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ALBERTA DEPARTMENT OF AGRICULTURE

WATER RESOURCES DIVISION

SOILS, GEOLOGY AND GROUNDWATER BRANCH

IRRIGATION STUDY BASIN

Annual Report No. 2

Calendar Year 1968

Prepared By Co-operating Agencies

Edited & Prepared By

Grant L. Nielsen

Hydrogeologist

EDMONTON, ALBERTA

March, 1969

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ALBERTA DEPARTMENT OF AGRICULTURE
Water Resources Division
Soils, Geology and Groundwater Branch

Second Annual Report

Irrigation Study Basin, 1968

I.H.D. Project

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Prepared by:

Alberta Dept. of Agriculture;
Water Resources Division
Canada Dept. of Agriculture;
Lethbridge Research Station
Canada Dept. of Energy, Mines
and Resources;
Inland Waters Branch
Canada Dept. of Transport;
Meteorological Branch
Research Council of Alberta;
Groundwater Division
St. Mary River Irrigation District

Edited and arranged by:

Grant L. Nielsen, P. Geol.
Hydrogeologist

Edmonton, Alberta.
March, 1969

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"When you can measure what you are speaking about and express it in numbers, you know something about it."

Lord Kelvin

INTRODUCTION

This second annual report is being arranged in a somewhat different manner from that used for the first. In 1968 the report was an edited compilation of individual agency submissions. This year, a committee of four has taken these agency submissions and written the report according to the various parameters to be measured. Thus, it is hoped that the significant points of interest will be arranged in a more logical sequence and be more readily available to the reader.

The annual meeting of the basin co-operators was held on March 18, 1969. During this meeting, the purposes of the study were discussed in some detail. Some felt that the goals, as described in the original submission, were too general; others disliked more specific objectives as being too detailed. The original submission reads, in part:

> "There is a need to obtain adequate data on all phases of the hydrological cycle within an irrigated area. This would involve a hydrologic inventory of all items of supply and disposal in the irrigation basin............. It is desirable to make a direct determination of all items in the hydrological equation."

Obviously, there is more to this study than just evaluating the various parameters to produce a hydrologic equation. The Research Co-ordinators' Seminar at Guelph (April 15-17, 1969) indicated that such parameters will seldom be measured to a high degree of precision in any case. The purpose of evaluating them is to discover their inter-relationships and the physical processes governing each. All of the individual objectives that the co-operators have considered are included in understanding these physical processes and inter-relationships.

Inasmuch as this report is intened mainly to be a report of stewardship, the contributors have summarized their data into an easily readable form. Should the reader wish further details on particular aspects of the basin, he is urged to contact either the individual contributor concerned, or the chairman.

Because most of the instruments will not survive temperatures below freezing, most data can only be collected during the growing season. The purpose of the study is to determine the effects of irrigation on the study basin, so it is not unreasonable to have the study period correspond to the irrigation period. There has been some difficulty in obtaining data for the winter months in order to compute an annual budget. An attempt will be made to solve this problem by treating the reporting year as running from November 1 to October 31, rather than to follow the calendar year. This will eliminate the problem of determining soil moisture on January 31. However, this cannot be done until November 1, 1969.

With respect to surface hydrologic parameters, for the purpose of this report, the reporting period is May 1, 1968 to September 30, 1968.

PRECIPITATION

Average precipitation for each month was computed by taking the simple average of the twenty-seven standard rain gauges for each month (Tables 1 and 2) and also by the planimetric method.

The average monthly rainfall by planimetric determination is given in Table 3 where it is found to be quite close to the values computed by simple averaging of the 27 sites, except for the month of June, where there is a 6% difference.

There is, of course, some variance in the way the isohyets may be drawn while maintaining consistency with the value at each site. An intensified rain gauge network would greatly reduce the propensity for error in drawing the lines. To illustrate the magnitude of this error, a planimetric averaging of Figure 6, which was drawn with respect to the season totals for each site, gives an average precipitation of 11.64 inches for the irrigated portion as compared to 11.47 inches, the sum of the five monthly planimetric values. This deviation is of the same magnitude as the deviation between the two methods of averaging.

With respect to the planimetric technique, there is additional error resulting from inaccuracy in following the lines on the map. In general, the sum of the individual areas as measured, "a", is not equal to the total area "A" as measured. It is therefore necessary to adjust the measured values "a" by a correction factor which will make the sum equal to the proper value. In practice, the average correction was 1.2 percent, the maximum being 2.5 percent.

It must be concluded, therefore, that the planimetric averaging technique does not yield more reliable rainfall data than the simple averaging of the various sites.

For Tables 3, 4, and 5, the planimetric values for season totals were used. The precipitation total for each crop has been taken to be the overall average for the appropriate portion of the basin (i.e. irrigated, non-irrigated.)

The rainfall for June and August was near normal while May and July were slightly below normal. Three days of snowfall beginning on September 20th brought more than three feet of snow with mixed rain bringing the September total very much above normal.

The total five-months precipitation varied from 10.5 inches in the northwest portion of the study area to 13.5 inches in the southwest portion. The total precipitation based on planimetric average was 241,900 acre-feet for the entire basin and 113,200 acre-feet for the irrigated portion, of which 81,400 acre-feet fell on irrigated acreage.

TABLE I. MONTHLY PRECIPITATION FOR 1968 GROWING SEASON (INCHES)

Site	May	June	July	August	September
1	1.52	4.09	0.60	1.13	3.95
2	1.43	3.62	0.61	1.70	4.37
3	1.72	3.58	0.83	1.90	4.19
4	1.72	3.29	0.62	1.66	4.11
5	1.77	2.75	0.65	1.69	4.00
6	2.57	3.11	0.57	1.63	4.21
7	1.38	3.21	0.56	1.47	3.72
8	1.86	3.79	0.63	1.68	4.28
9	1.97	4.12	0.65	1.47	4.22
10	1.79	4.42	1.02	1.57	3.77
11	1.60	4.44	0.73	1.42	4.95
12	1.92	3.91	0.81	1.78	3.76
13	1.30	4.19	0.61	1.43	3.38
14	1.52	4.19	0.65	1.70	5.19
15	1.53	3.19	1.03	1.68	4.02
16	1.61	3.53	0.64	2.28	4.77
17	1.81	3.06	0.70	1.98	5.08
18	1.73	3.39	1.14	1.86	4.75
19	2.05	2.88	1.21	2.01	4.88
20	1.40	2.62	0.63	1.65	4.02
21	1.86	3.17	0.49	0.92	3.81
22	2.10	3.43	1.17	1.24	4.06
23	1.35	3.91	0.65	1.24	4.39
24	2.06	2.71	0.67	1.83	4.05
25	1.71	3.41	0.52	1.11	4.40
26	1.79	2.80	1.11	2.19	5.04
27	-	-	-	1.54	4.62
Average	1.73	3.49	0.75	1.62	4.30
Normal	2.09	3.20	1.69	1.64	1.36

AVERAGE RAINFALL (INCHES) TABLE 2

	May	June	July	August	September	Total
Rainfall Average (27 sites)	1.7	3.50	0.8	1.6	4.3	11.9
Planimetric Average (entire basin)	1.7	3.30	0.8	1.6	4.3	11.7
Planimetric Average:						
Irrigated Portion	1.7	3.4	0.56	1.5	4.3	11.5
Non-Irrigated Portion	-	-	-	-	-	12.0

EVAPOTRANSPIRATION (INCHES) MAY 1 TO SEPTEMBER 30 TABLE 3

Crop	Estimated Use of Pre-Season Moisture	Precipitation during growing season	Effective Irrigation	Evaporation While Fallow	Total
Grain (not irrigated)	3.0	5.1	--	1.6	9.7
Forage (not irrigated)	2.4	11.9	--	--	14.3
Grain (irrigated)	3.0	5.1	2.3	1.6	12.0
Forage (irrigated)	2.4	11.9	6.1	--	20.4
Sugar Beets	0.5	10.9	8.8	0.3	20.5
Peas	0.5	4.5	4.1	2.1	11.2
Misc. Vegetables	0.5	7.0	4.1	0.8	12.4

IRRIGATED CROP ACREAGE AND WATER DATA (x 100) TABLE 4

Crop	Area (acres)	Evapotranspiration (acre-feet)	Pre-Season Moisture (acre-feet)	Precipitation (acre-feet)	Effective Irrigation (acre-feet)
Grain	384	384	180	341	74
Vegetable	120	178	57	120	74
Forage	158	269	75	156	81
Summerfallow	165	67	94	195	--
Grassed Area					
Borrow Pit	12	20	5.7	11.5	8
Canal Bank	18	29[a]	4	17.6	12
Phreatophytes	12	24	36	11.4	--

a) Sub-irrigation derived from canal seepage.

NON-IRRIGATED CROP ACREAGE AND WATER DATA (x 100) TABLE 5

Crop	Area (acres)	Actual Evapotranspiration (Acre-feet)	Pre-Season Moisture (acre-feet)	Precipitation (acre-feet)
Grain	782	632	325	771
Forage	295	351	128	290
Summerfallow	360	120	143	358
Grassed Area				
Borrow Pit	18	20	7.3	18.4
Phreatophytes	30	60[a]	90	30

a) Estimate

NON-CROPPED ACREAGE AND WATER DATA (x 100) TABLE 6

	Area (acres)	Evaporation (acre-feet)	Precipitation (acre-feet)	Runoff (acre-feet)
Water Surface				
Canals, laterals ditches	9.7	17.7	9.2	-
Lakes, ponds, sloughs, borrow pits	16.9	37.5	16.3	-
Non-Arable				
Urban	43.2	21.0	42.1	8.1
Road (paved, gravel rail)	12.3	2.0	12.0	10.0
Uncultivated	3.4	3.3	3.3	-

EVAPORATION DATA-CLASS "A" PAN (INCHES) TABLE 7

Site	May	June	July	August	September	Total
1	7.35	8.12	8.83	6.63	4.98	35.91
4	7.23	8.41	8.97	6.32	5.00	35.93
26	6.87	9.16	9.80[a]	6.88	5.51	38.22
Average	7.15	8.56	9.20	6.61	5.16	36.69

Variance ±4%

(a) Hailstorm on July 29th caused some water loss from this pan due to splashing. With some uncertainty, the true evaporation has been assumed to be comparable to the other two sites and this loss has accordingly been estimated to be 1.04 inches. The figure in the Table has been corrected accordingly.

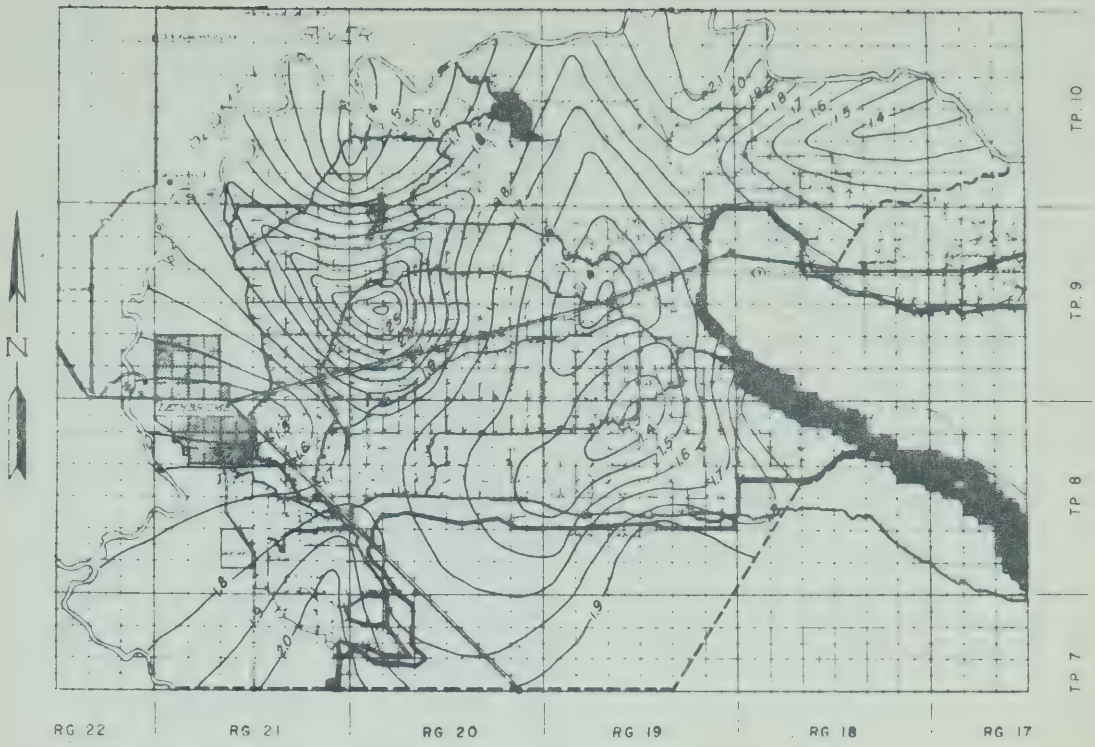


FIGURE 1 Precipitation — May, 1968 (inches)

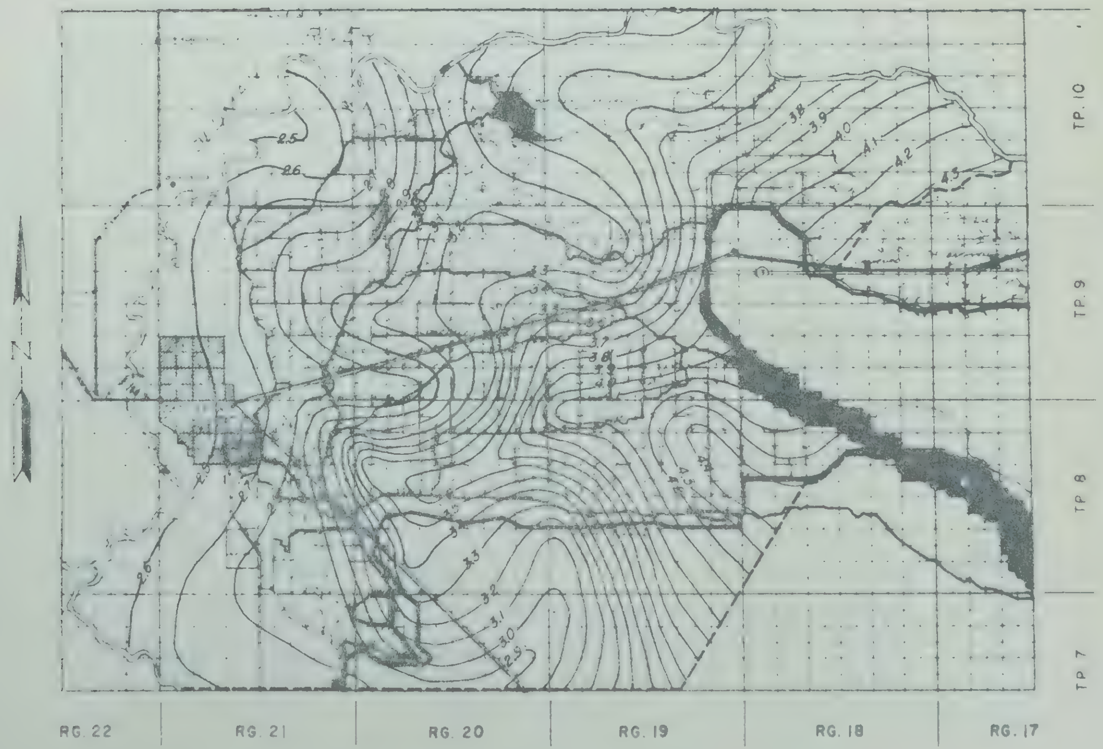


FIGURE 2 Precipitation — June, 1968 (inches)

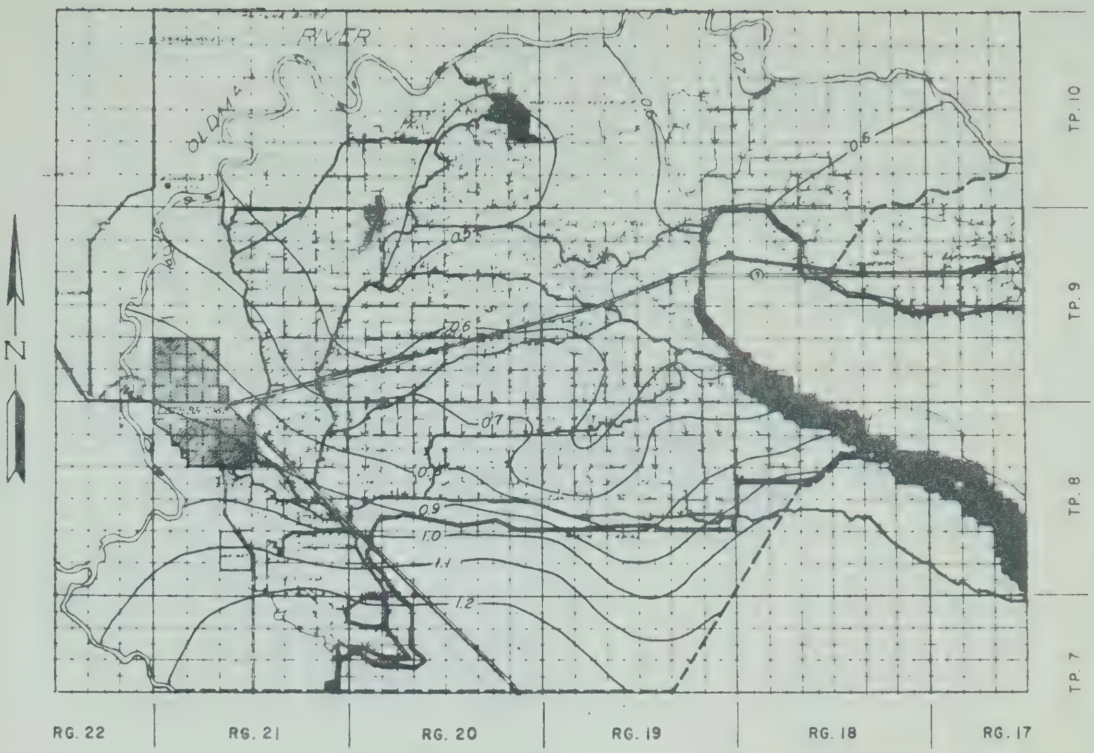


FIGURE 3 Precipitation — July, 1968 (inches)

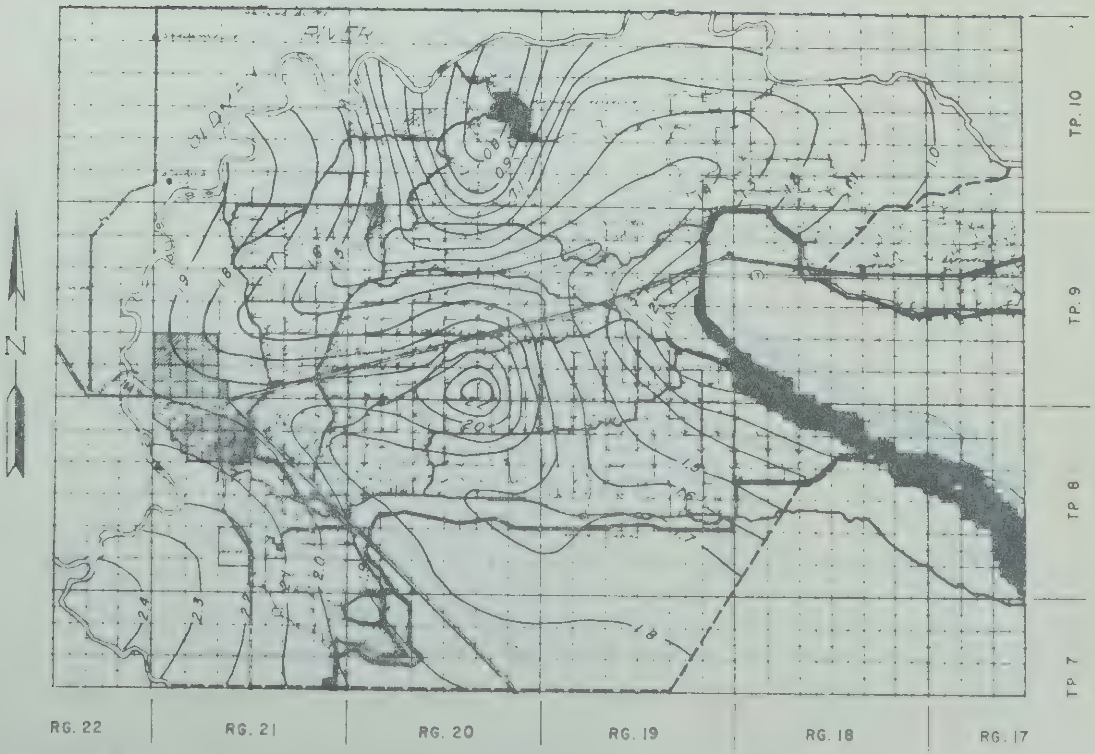


FIGURE 4 Precipitation — August, 1968 (inches)

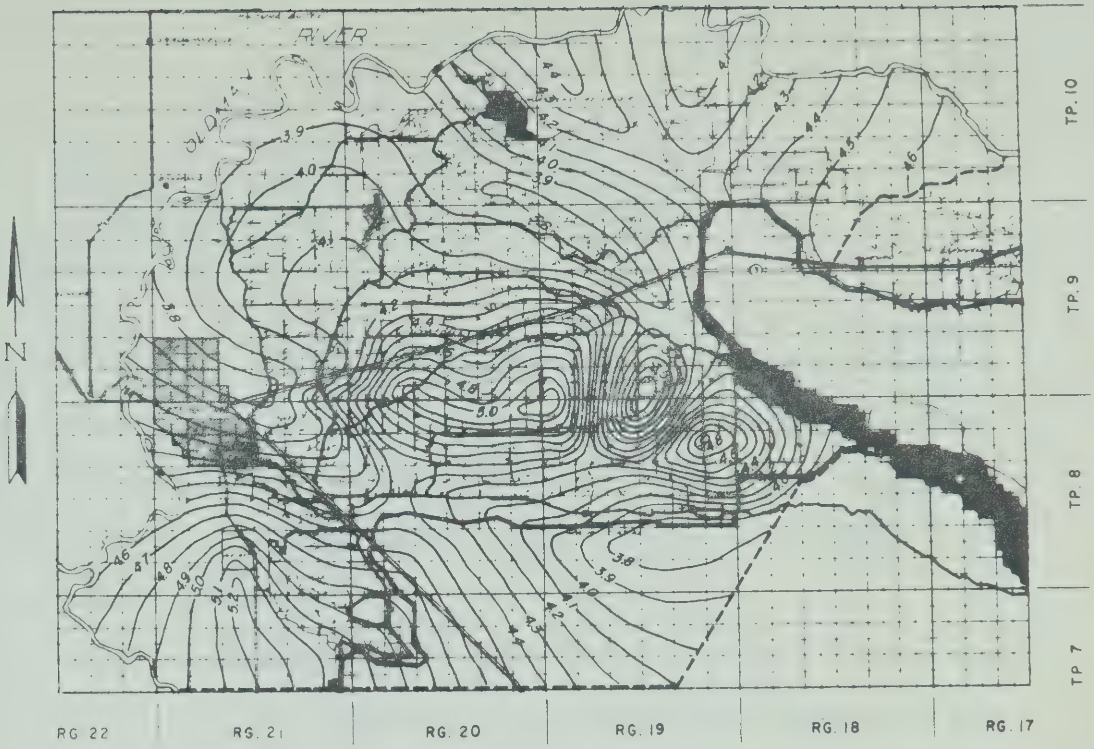


FIGURE 5 Precipitation — September, 1968 (inches)

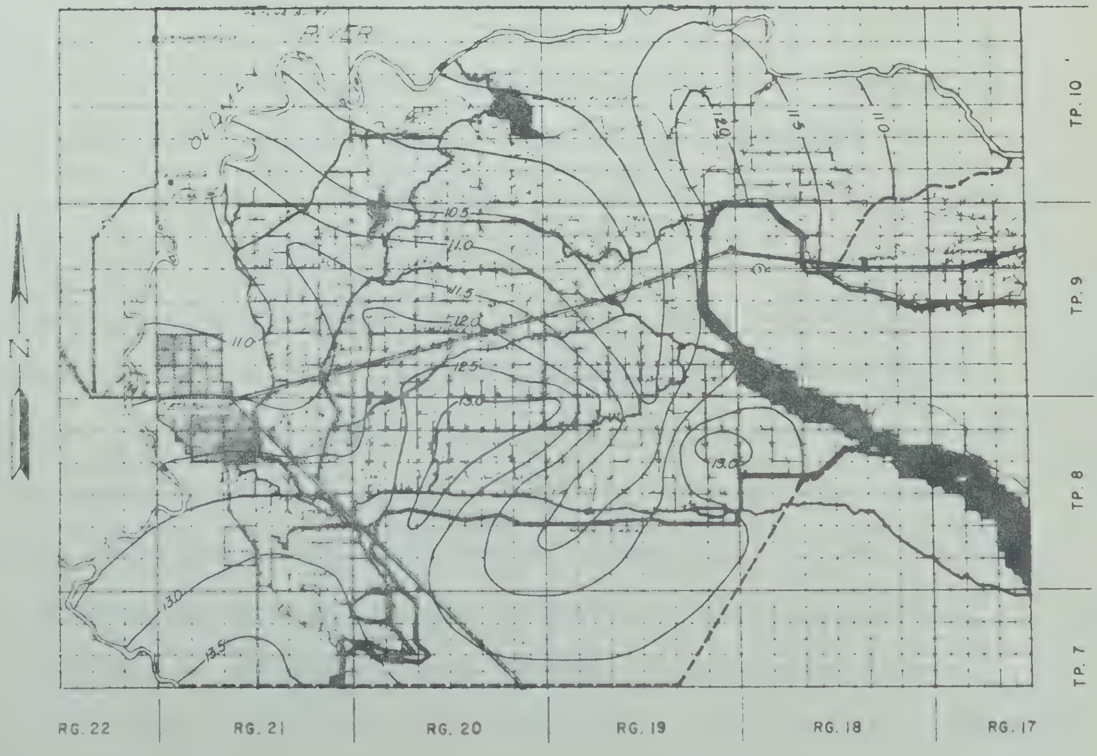


FIGURE 6 Precipitation — May to September Total (inches)

SURFACE RUNOFF

Rainfall received during the growing season resulted in small amounts of runoff. An estimated 300 acre-feet were included in the measured effluent through Bountiful Coulee and Six Mile Coulee. Most of this resulted from the snow storm of September 20-22. Small flows measured in some of the other coulees were insignificant.

Most runoff occurred from hard surface roads. That which fell on such surfaces in urban areas was discharge to the Oldman River through storm sewers. Runoff from roadways in rural areas has been credited to borrow pits. The infiltration capacity of the soil was essentially greater than the precipitation rate for all storms during 1968, so the remaining portion of surface runoff (that which collects in sloughs, borrow pits, etc.) has been ignored.

Because of the large precipitation for the snow storm of September 20-22 (4.04 inches) and its rapid dispersal under chinook conditions, a more than typical amount was lost to evaporation and runoff. Estimates of 5 per cent and 25 percent of the precipitation falling on fields have been given for evaporation and runoff respectively. The evaporation and runoff are then estimated to be 1,360 and 6,790 acre-feet respectively from irrigated fields and 2,510 and 13,560 acre-feet respectively from non-irrigated fields. Runoff from roadways was 410 acre-feet. Runoff to Six Mile Coulee and Bountiful Coulee are estimated to be 400 acre-feet. Water which collected in borrow pits was then estimated to be 20,350 acre-feet. Assuming that there were 190 acre-feet of additional storage potential in the borrow pit root zone, and estimating a percolation rate twenty times greater than the surface

evaporation rate (1), there are 17,480 acre-feet of additional evaporation. Total surface runoff to the Oldman River is 6,659 acre-feet, or 16.7 acre-feet per square mile of the basin. Such statistics must be viewed with caution, because by far the largest part of the basin contributes no runoff whatsoever to the river. As may be seen in Table 14, there were some 20,000 acre-feet of additional runoff, but it flowed only to adjacent borrowpits and ponds.

The area contributing runoff to the Oldman River, although small, is variable, and depends upon such factors as pre-season surface storage, pre-season soil moisture conditions, quantity of winter snow cover, and rate of summer precipitation.

(1) The average evaporation rate for the period after the storm was .004 inches per hour, the saturated infiltration rate is estimated to be .06 inches per hour and the infiltration surface averaged 30 percent greater than the evaporation surface during the period when water remained in the borrow pits.

EVAPOTRANSPIRATION AND LAND UTILIZATION

Evapotranspiration in general can be estimated as the sum of precipitation during the period of growth, irrigation, a certain portion of the available pre-season moisture, and an amount computed by treating the cropped area as summerfallow during the periods before seeding and after harvest. This has been done for the basic crop groups and is given in Table 3.

The data for borrow pits given in Tables 4 and 5 were estimated by treating them as forage areas.

Latent evapotranspiration has been correlated to class A pan evaporation. (2) (3) This method was used to determine the actual evapotranspiration for the grass growing on canal banks and is based on the assumption that canal seepage will maintain a high level of available moisture.

The land in the basin has been differentiated with respect to basic texture of the soil surface in Figure 7, and with respect to irrigated and non-irrigated in Figure 8. The cropped land area within the non-irrigated portion of the basin is 122,500 acres. The cropped land area in the irrigated portion of the basin is 115,700 acres. However, 29,000 acres of this are classed as not irrigated because they represent higher elevation areas in fields than that which is surface irrigated, or which for other physical reasons does not have access to water. In addition to this, 30 percent of the borrow pit did not receive irrigation runoff because it was too high in elevation. Therefore, the non-irrigated land use data, Table 5, includes

(2) Hobbs, E.H. and Sonmor, L.G., 1964. Irrigation scheduling. Research for farmers, 9 (4), 4-5

(3) Unpublished Data, Lethbridge Research Station

those acreages from within the boundary of the irrigated portion of the basin which are not irrigated, while the data in Table 4 does not include these acreages.

With respect to the corresponding data in the 1967 report, the amount of land under water and the non-arable land remained the same while the acreage covered by phreatophytes decreased slightly because of land clearing along canal and laterals. However, there were a number of oversights in the land use data for the 1967 report. Some land is taken up with secondary irrigation laterals and farm irrigation ditches. This represents a reduction in crop acreages and an increase in evaporation surface, although some of this is under water during only part of the season. This report then gives a more accurate distribution of land use than did the 1967 report.

EVAPORATION

Evaporation data from Class A evaporation pans is given in Table 7. Evaporation data corrected to shallow lake surface evaporation by the method of Kohler, et. al. (1955) (4) is given in Table 8. This data was used to compute evaporation from all open water surfaces in the basin.

The highest daily loss from the pans was 0.58 inches for June 26, for which date the lake evaporation reading was 0.38 inches. The highest monthly total was for July.

---

(4) Kohler, M.A., Nordenson, T.J. and Fox, W.E., 1955. Evaporation from pans and Lakes. U.S. Weather Bureau Research, Paper 38.

EVAPORATION DATA CORRECTED TO LAKE EVAPORATION (INCHES) TABLE 8

Site	May	June	July	August	September	Total
1	5.6	6.1	6.6	4.9	3.4	26.6
4	5.5	6.2	6.7	4.6	3.5	26.4
26	5.2	6.5	7.0	4.8	3.7	27.2
Average	5.4	6.3	6.7	4.8	3.5	26.7

Variance ±2%

EVAPORATION FROM OPEN WATER SURFACES TABLE 9

	Open Water Surface (Acres)	Evaporation Loss (Acre-feet)
1. Main canal and laterals[a]	620	1,370
2. Secondary laterals[a]	120	210
3. Farm Ditches[a]	180	210
4. Lakes[a]	1,060	2,360
5. Dugouts[a]	75	140
6. Ponds, Sloughs, etc.	610	1,360
7. Borrowpits[b]	20	1,240
	2,687	6,890

(a) Evaporation period reduced to that portion of the season for which water is present.

(b) Includes evaporation of storm and irrigation runoff into non-ponded borrowpits.

IRRIGATION AND WATER FLOW DATA

Irrigation canal flow data (Table 9) was obtained from S.M.R.I.D. ditch-rider records and also from the records of the Inland Waters Branch. Data for water supplied to farmers from the canal systems was obtained from the S.M.R.I.D. ditch-rider estimates.

Some problems were encountered by the Inland Water Branch in the operation of the existing gauging stations because of shifting control conditions, poorly defined rating curves and vandalism.

The percentage of return flow leaving the study basin through Nolan Coulee is very small. This station will not be operated in 1969. The Six Mile Coulee (near Lethbridge) gauging station has been subjected to severe vandalism throughout the 1968 season. To overcome this problem, an attempt will be made to relocate the station for the 1969 season. The gates at the Chin Reservoir Outflow Canal to Bountiful Coulee remained closed in 1968. The minor flow which was recorded during the sason was a result of leakage past the gates.

Several inspection trips were made to selected miscellaneous ungauged, return flow coulees. Very little flow was found in any of the coulees at any time and what flow existed had no relation to the gauged return flows. Thus this ungauged measurement program is to be discountinued. It is suggested that the total flow in the ungauged coulees can best be determined by applying some type of rainfall-runoff coefficient.

Discharge measurements were taken twice a month at the Taber Irrigation District Canal near Cranford but in spite of this measuring program the computed mean daily discharges are only approximate. The rating curve was extremely unstable because of profuse weed growth in the canal, resulting in

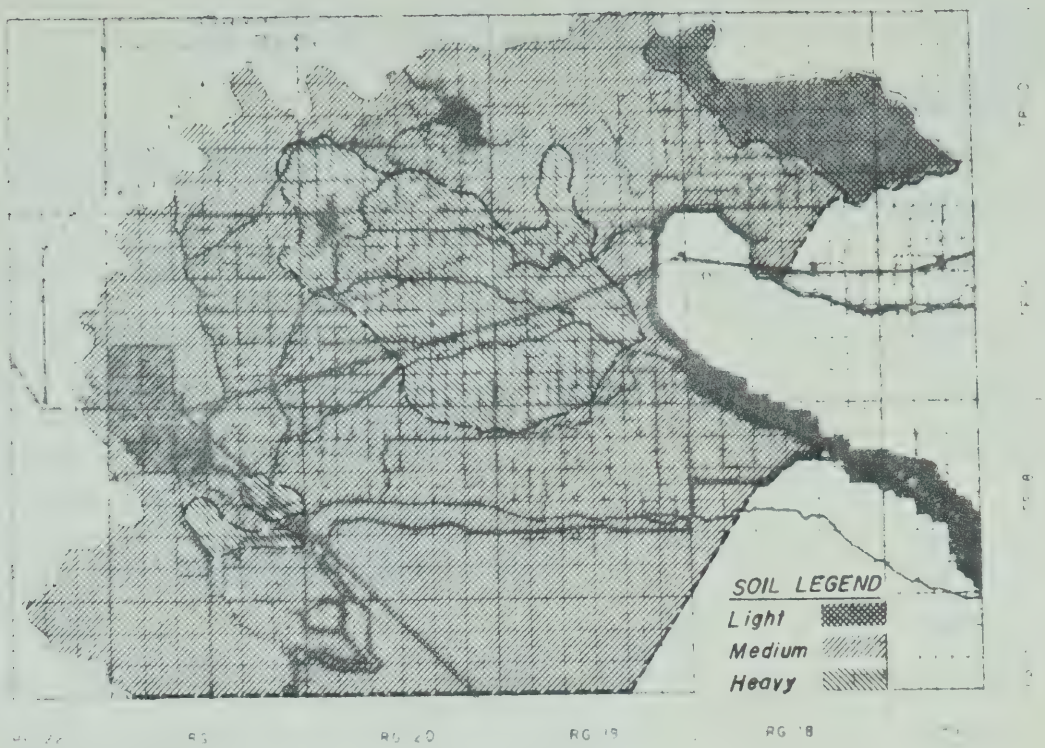


FIGURE 7 Basic Surface Soil Textures Within Study Area

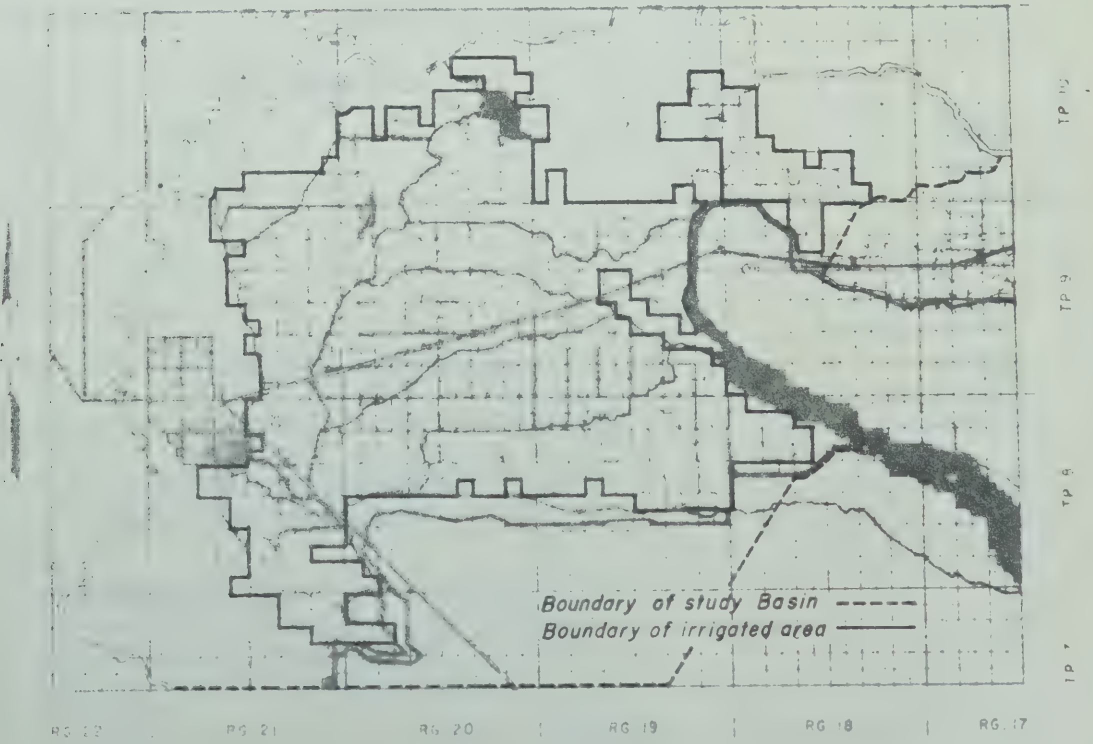


FIGURE 8 Boundary Locations Map

WATER FLOW DATA (MAY 1 TO SEPTEMBER 30)

TABLE 10

	(Acre-feet)
Main Canal in-flow (at Lethbridge-Coaldale diversion)[a]	267,486
Main Canal out (to Chin Reservoir)[a]	168,041
Delivered to Lethbridge-Coaldale laterals[a]	91,096
Delivered to Readymade extension (lateral 1)[c]	2,464
Irrigation Turnout from Readymade extension lateral[b]	1,288
Readymade effluent to Chin Reservoir[e]	1,030
Effluent from Lethbridge-Coaldale system	
Chin Butte Spillway (Return to Main Canal)[a]	7,865
Malloy Drain[a]	19,451
Cameron Spillway (et. al.)[c]	10,719
To Bountiful Coulee[c]	3,235
Lateral 10[c]	414
To Henderson Lake[a]	170
Irrigation Turnout to secondary laterals[e]	46,392
Effluent from secondary laterals	
To Farm Turnouts[b]	41,602
To Six Mile Coulee[e]	1,000
To Nolan Coulee	NIL
To Malloy Drain[f]	1,000
Six Mile Coulee (mostly precipitation runoff)[c]	2,200
T.I.D. Canal inflow (from Chin Coulee Spillway)[a]	4,799
T.I.D. Exit from Basin (at Cranford)[c]	5,626
From T.I.D. to Secondary Laterals[d]	310

Sources:
(a) Read by S.M.R.I.D.
(b) Estimated by S.M.R.I.D. Ditchriders
(c) Read by Inland Waters Branch
(d) Estimated by T.I.D. Ditchriders
(e) Estimate
(f) Includes estimated 300 acre-feet precipitation runoff, 900 acre-feet from subsurface drainage

CANAL SEEPAGE TABLE 11

Main Canal	13,650
T.I.D. Canal [a]	500
Main Lethbridge-Coaldale laterals	5,500
Secondary laterals	980
Less subterranean irrigation of grass along canal banks	-1,180
Contribution to deep percolation	19,450 acre-feet

ADDITIONAL CANAL DATA TABLE 12

	Area (acres)	Precipitation (acre-feet)	Evaporation (acre-feet)
1. Main Canal	240	230	530
2. Primary Lateral	380	370	840
3. Readymade Extension	3	3	5[b]
4. Lethbridge-Coaldale Secondary Laterals	115	112	205[b]

(a) That portion of the basin which is bounded on the north by Bountiful Coulee and on the south by the S.M.R.I.D. Main Canal to Medicine Hat proved to be a little cumbersome in the basin analysis, and was further complicated by the inaccuracy of flow data for the T.I.D. Canal. Inasmuch as runoff from this area into Bountiful Coulee is negligible, it is not really necessary to include it in the study basin, and it will in future be deleted from the study basin.

(b) Effective average evaporation surface was less than for precipitation (80%) due to low flow levels in May and early September when precipitation was low.

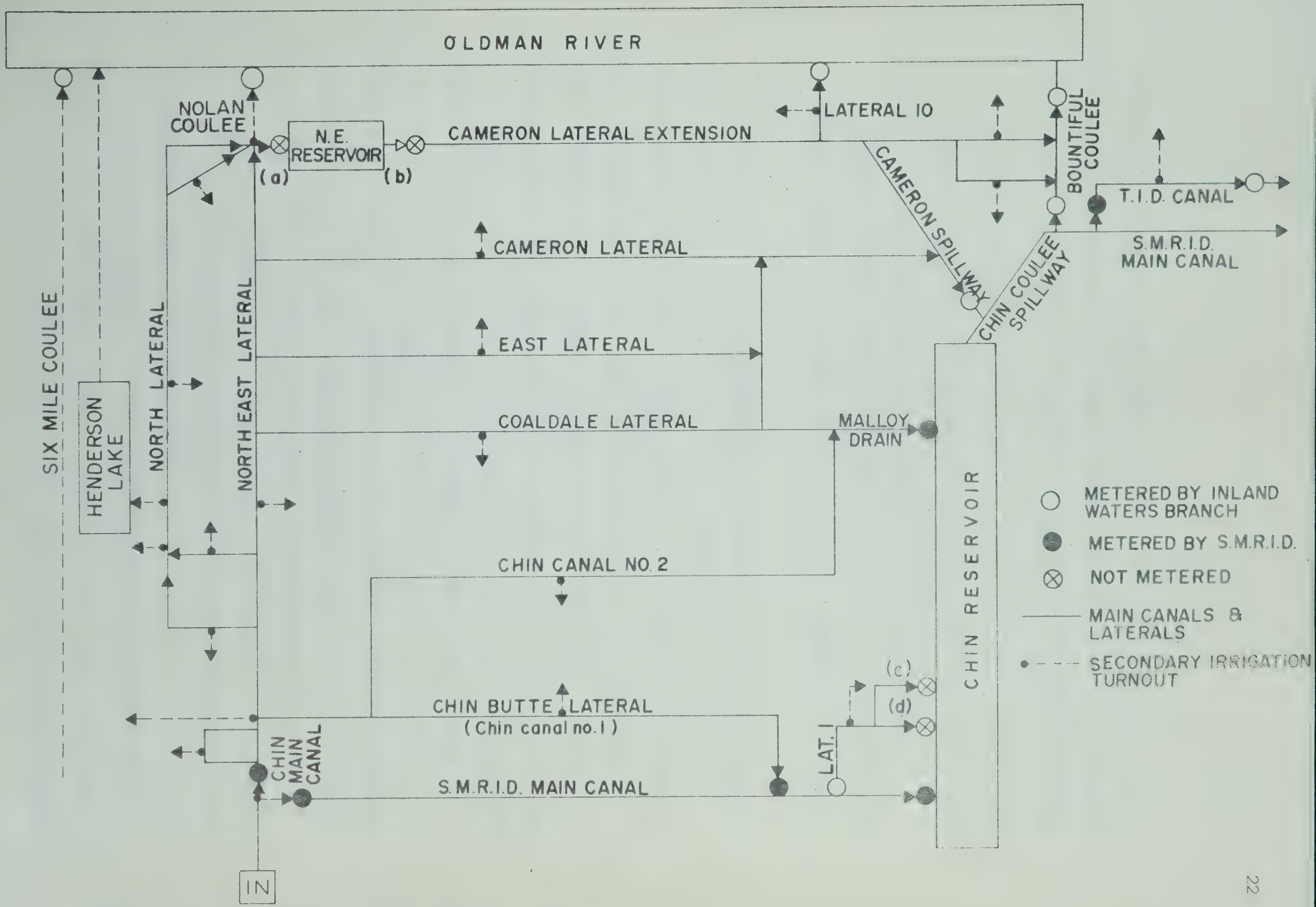


Figure 9 — SCHEMATIC — MAIN CANALS AND LATERALS

shifting bed conditions. Since the accuracy of the daily discharge data at this station is very poor, the amount of water which was used for irrigation from the canal is not easily determined and at best will be only an estimate.

A. CANAL SEEPAGE

The flow data (Table 10) has been analysed in relation to the schematic (Figure 9) of the flow system for the purpose of evaluating seepage.

Seepage calculations for that portion of the T.I.D. Canal that is within the basin are only an estimate because of obvious inaccuracy of outflow data.

The most precise data on seepage was obtained for the main S.M.R.I.D. Canal south of Lethbridge. The water lost to September 30 from the entire portion of the canal within the basin (prior to its flowing into Chin Reservoir) was 13,650 acre-feet. This is that water which cannot be accounted for by evaporation, irrigation, turn-out, discharge into Chin or canal storage on September 30. The seepage rate is computed to be 0.17 inches per hour.

There are broad drainage areas leading into some of the canals upstream from where discharge is metered. The foregoing analysis ignores storm runoff from these drainage areas back into the canal system. This may be appreciable for storms such as occurred on September 20-22, wherein 4 inches of precipitation fell as snow. Such runoff becomes another input to the system and implies greater losses to canal seepage than computed, but also less deep percolation than computed from borrow pits and other areas. Ignoring this parameter does not significantly affect the computed total contribution to groundwater recharge for the basin.

Seepage was computed in the Readymade extension (a secondary lateral) by assuming the same seepage rate as for the Main Canal. This gives a seepage value of 140 acre-feet for this lateral, and along with the precipitation

and evaporation data for this lateral is the basis of the estimate for runoff to Chin Reservoir from the Readymade area.

Seepage on the main laterals and secondary laterals may be approximated by assuming that the inflow and outflow of the North East Reservoir are equal. The total seepage in these laterals is then calculated to be 7,180 acre-feet. There is no way of knowing the validity of the assumption until such time as these flows are monitored. In apportioning this seepage (Table 11) it has been assumed that the average seepage rates for both the primary and secondary laterals are the same. Hydraulic Conductivity is computed to be 0.036 inches per hour and is much lower than for the main canal. Presumably this is due to a lower permeability for the lacustrine deposits in the irrigated part of the basin than for the moraine where the main canal is located.

The symptoms normally associated with high canal seepage have not been reported near the main canal. The computed hydraulic conductivity then suggest high vertical permeability of the glacial till. The canal section has undergone a certain degree of modification since the flow calibration. Since the parameter of significance is the difference between inflow and outflow (which is small in relation to the total flow) a small error in flow data could cause an appreciable error in the seepage figure.

The seepage analysis might be considerably benefited by piezometer installations along the main laterals to determine correct seepage rate data.

B. SOIL MOISTURE

For the purposes of this study, that part of soil moisture which is not available to plants (that water held against 15 bars of tension) has been treated as a part of the soil and not part of the water balance. Four foot root zone water storage for the basin, was computed by using generally accepted data for water storage characteristics of light, medium and heavy soils

for the area. The available storage capacity data used were 5.6 inches, 7.5 inches, and 9.0 inches, respectively. Moisture falling on the soil in quantities great enough to exceed this storage limit are then assigned to the water tables as deep percolation.

Pre-season plant available moisture to a four foot depth for the irrigation portion of the basin was estimated to be 5.9 inches for heavy soil and 5.05 inches for medium soil, accounting for 76,400 acre-feet of pre-season storage. This moisture has been assigned to crop acreages on a prorated basis.

Similarly, the pre-season plant available moisture for the non-irrigated area was estimated to be 5.6, 4.75 and 3.9 inches for heavy, medium and light soils, respectively, accounting for 60,300 acre-feet of pre-season storage.

Soil moisture storage in phreatophyte areas has been assumed to be a condition of saturation throughout the season, that is 36 inches for a six foot root zone.

The effective contribution of irrigation was computed by assuming 20% evaporation from sprinklers, 20% runoff from surface irrigation, 20% deep percolation due to non-uniform surface distribution of irrigation by either method, and by estimating the seepage from ditches and dugouts.

Dugout seepage has been computed by assuming a seepage rate of 0.12 inches per hour and head ditch seepage by assuming a seepage rate of 0.20 and total period of use of one month. Deep percolation due to over-irrigation is calculated by assuming that 20% of the water applied to the field is lost to deep percolation. Deep percolation from borrow pits was calculated by assuming that the average infiltration rate was twenty times as large

as the evaporation rate, and by estimating the capacity of the four-foot grass root zone for additional storage.[5]

Much more rainfall was received on summerfallow than was needed to replace evaporation and maintain field capacity. The excess has been assigned to deep percolation.

The estimated seepage data is given in Table 13. Field investigations should be conducted to test these estimates to determine their validity and make corrections where necessary.

ESTIMATED DEEP PERCOLATION[6] TABLE 13

Dugouts	4,100
Irrigation ditches	3,170
Borrow pit	21,840
Summerfallow	19,200
Over-irrigation	5,800
Urban	490

---

(5) The average evaporation rate for May-August was .0075 inches per hour. The estimated unsaturated percolation rate for fully grassed areas is 0.15 inches per hour.

(6) The term "deep percolation" refers in this publication to that water percolating below the root zone. It has not necessarily reached the water table.

Table 14 shows the distribution of hydrologic measurements, calculations, and estimates for the 1968 crop year. They have been broken down into three main headings: surface water, root zone, and below the root zone. Each is subdivided into input, output, and change in storage. If all figures were correct, input should equal output plus storage change. In order to balance the distribution for the root zone, 21,760 acre-feet of seepage were placed in Storage Change.

TABLE 14

DISTRIBUTION OF HYDROLOGIC PARAMETERS (MAY 1 TO SEPTEMBER 30, 1968)
(acre-feet)

A. SURFACE WATER ZONE

	Input			Output			
	Precipitation	+Diversion	Runoff	Evaporation	-Diversion	Seepage	Storage Change
Main canal and laterals	600	268,100	-	1,370	247,480	19,150	+700
Secondary laterals	115	47,305	-	210	43,370 3,030	980	0
Irrigation head ditches and dugouts	240	43,370	-	350	35,820	7,270	0
Ponded borrow pits	20	-	30	50	--	20	- 20
Ponds, sloughs	600	170	-	1,360	--	260	-500
Lakes and reservoirs	1,030	-	-	2,360	--	450	-880
	2,605	358,945	30	5,700	328,700	28,130	-700
		TOTAL	361,580		TOTAL	361,830	

TABLE 14 (Continued)

B. ROOT ZONE

	Input			Output				
	Precipitation	Seepage	Irrigation	Deep Percolation	Evaporation	Consumptive Use	Runoff	Storage Change
Brought forward	-	28,130	-	-	-	-	-	+21,760
Canal banks	1,760	1,180	-	-	-	2,900	-	-200
Irrigated fields	82,200	-	35,820	11,150	3,860	89,800	6,890 4,660	+1,680
Non-irrigated fields	141,900	-	-	13,800	2,510	110,300	13,560	+1,670
Irrigated borrow pits	1,150	-	4,660 6,580	9,240	680	2,000	-	+ 460
Non-irrigated borrow pits	1,840	-	13,230	11,860	500	2,000	-	+710
Phreatophytes	4,140	-	4,280	-	-	8,420	-	0
Uncultivated	330	-	-	-	330	-	-	0
Non-arable	5,410	-	-	490	550	2,560	1,810	0
To Oldman River	-	-	-	900	-	-	5,760	
	238,730	29,310	64,570	47,440	8,430	217,980	32,680	+26,080
	TOTAL 332,610					TOTAL 332,610		

TABLE 14 (Continued)

C. BELOW ROOT ZONE

	Input Deep Percolation	Output Non-Saturated flow	Output Groundwater Discharge	Change of groundwater storage
Brought forward	47,440	26,640[a]	17,800	+3,000[a]
	TOTAL 47,440		TOTAL 47,440	

(a) Estimate

GROUNDWATER

Although many of the piezometer nests have not yet reached equilibrium, a preliminary interpretation of available data has permitted some conclusions regarding groundwater flow. It appears that almost the entire basin forms a recharge area, i.e., groundwater percolates down from the land surface. Only the area adjacent to the river and major coulees contributes to regional groundwater discharge. (see Figure 16). This limited area of discharge is a result of the land surface configuration. That is, practically the entire basin is a relatively high upland, bounded by steep-sloped valleys whose area is limited.

Some of the usual groundwater discharge features may be seen in the discharge portion of the basin, i.e. salt deposits, phreatophytes, barren ground, sloughs, etc. In an irrigated area, such features must be interpreted with extreme caution. Seepage and overflow from canals can create most of the same phenomena in recharge areas, particularly perennial sloughs and salt buildup.

The permeability of most formations, both bedrock and surficial, is extremely low in the study basin. The Saskatchewan Gravel, however, is relatively much more permeable, such that the bulk of groundwater flow is concentrated in this one horizon. No piezometric head exists in the Saskatchewan Gravel adjacent to its exposures along the Oldman River. The rest of the Saskatchewan Gravel does have a piezometric head. There is a perched water table above the gravel within the glacial and interglacial lacustrine materials. Its approximate configuration is shown in Figure 11. Since the gravel is truncated to the west and north by the Oldman River, the only sources of recharge for the main channel are the tributary channels to the

south, and direct vertical infiltration of precipitation and irrigation water from the land surface.

Slug tests in several piezometers have made possible the calculation of some permeabilities for glacial deposits. Laboratory tests were also conducted on till cores, and these yielded permeabilities of the same order of magnitude as did the slug tests (Table 15).

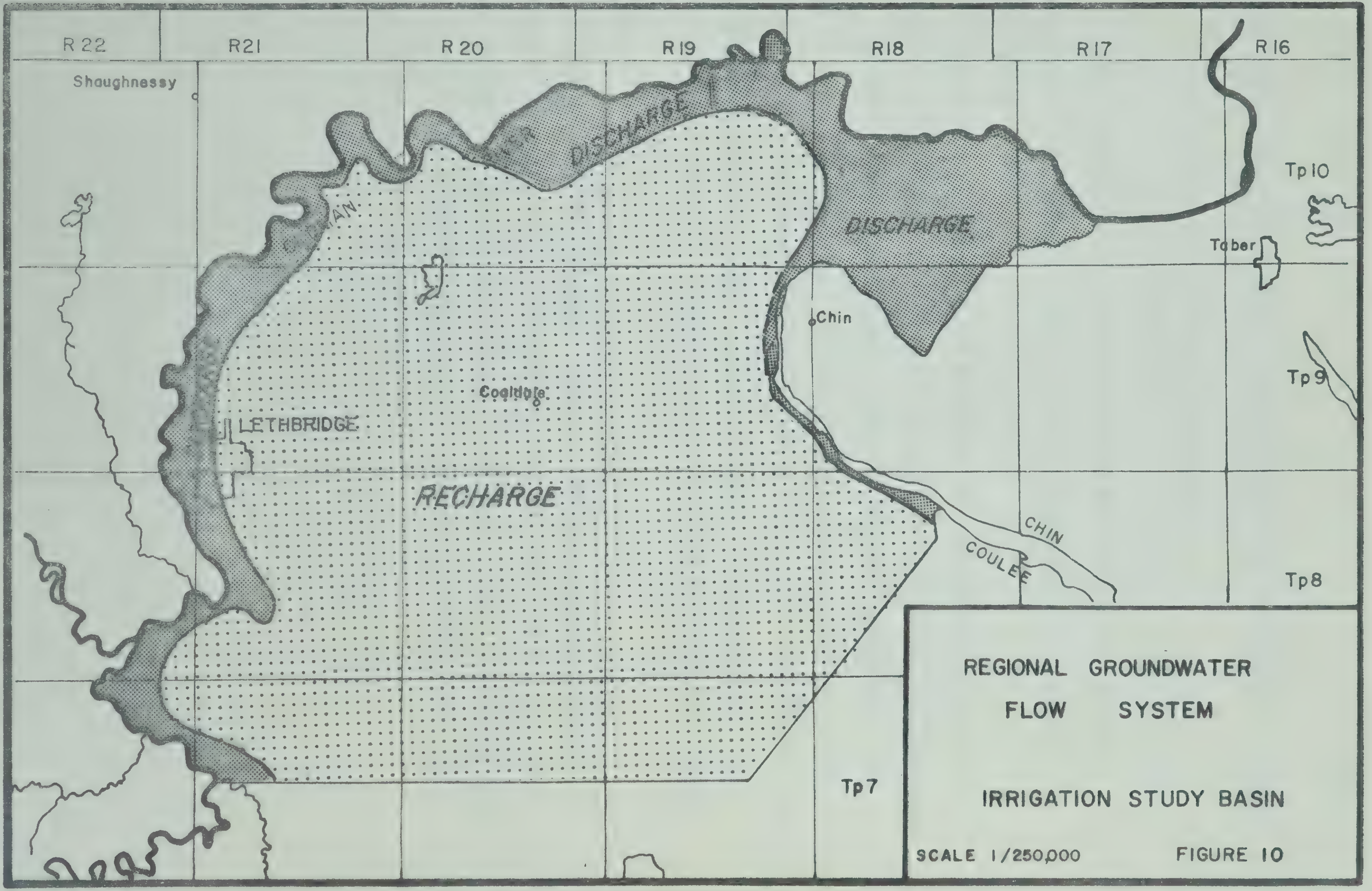
Hi-Rate Drilling completed the groundwater instrumentation of the basin during the late summer of 1968. In addition to installing piezometer nests, this company drilled and pump-tested a well in the Oldman Formation in Lsd. 5-22-8-21-W.4th. Water was produced from a fine sandstone aquifer at 318 to 341 feet of depth. Static level was 192 feet, transmissivity was 15 gpd per foot, and the safe pumping rate was 1 gallon per minute.

Readings were discontinued on 47 shallow water table wells, clustered in the Junior College area and the south end of the city of Lethbridge. These had been installed several years ago to monitor shallow water table problems for the city, and have now served their purpose.

The groundwater recharge rate into the basin has been calculated by Toth's technique, as used for the Three Hills area. The Saskatchewan Gravels and bedrock formations (Oldman, Foremost and Bearpaw Formations) were analysed separately.

Saskatchewan Gravels underlie 235 square miles of the basin, of which 181 square miles are recharge area, and 54 square miles are discharge area. In 1968, precipitation for the basin, averaged from Airport and Research Station records, was 16.82 inches. In addition, irrigation for the 1968 season averaged 3.03 inches for the entire basin. Total influent water, then, was 19.85 inches.

The average drop in water levels over the winter of 1968-69 at six sites in Saskatchewan Gravels was 1.3 feet. Assuming a specific yield of



REGIONAL GROUNDWATER FLOW SYSTEM

IRRIGATION STUDY BASIN

SCALE 1/250,000 FIGURE 10

0.1 for gravel, the average depth of water exchange for 4.75 months of ground frost was

$$0.1 \times 1.3 \times 12 = 1.56 \text{ in./ } 4.75 \text{ months}$$

$$= 3.9 \text{ in./year}$$

Total recharge rate is therefore (3.9/19.85) x 100 = 20%, and the annual volume of recharge is 3.9 x 181 x 640 = 38,000 acre-feet, or 109 gpm/sq. mile.

Bedrock aquifers underlie the remaining 164 square miles of the basin. Of this area, 114 square miles are recharge and 50 square miles are discharge.

The average drop in water levels over the winter of 1968-69 for five sites in bedrock was 0.5 feet. Using a specific yield of 0.05 for bedrock, the average depth of water exchange was 0.05 x 0.5 x 12 = 0.3 in./ 4.75 months, or 0.76 inches per year. Total recharge to bedrock was (0.76/19.85) x 100 = 4% of all influent water, or $\frac{0.76}{12} \times 114 \times 640 = 4620$ acre-feet, or 21 gpm/ sq. mile.

Total groundwater recharge in 1968 was therefore approximately 4620 + 38,000 = 42,620 acre-feet, or 55 gpm/sq. mile. Of this, 11% was into bedrock, and 89% into Saskatchewan Gravels. According to Table 11, 28,130 acre-feet of this, or 66 percent originated as deep percolation from below the root zone between May 1 and September 30.

PERMEABILITIES OF SURFICIAL MATERIALS — TABLE 15

Location	Horizon	Depth	Thickness	Permeability (Meinzer Units)	Transmissibility (Meinzer Units)
NE-35-6-22-W.4	Lenzie Silts	17	20	7.25×10^{-5}	1.45×10^{-3}
NE-35-6-22-W.4	Lower Till	35	40	7.21×10^{-5}	3.3×10^{-3}
NW-21-7-20-W.4	Upper Till	33.1	90	2.64×10^{-5}	2.38×10^{-3}
NW-21-7-20-W.4	Upper Till	52.8	90	3.62×10^{-5}	3.3×10^{-3}
NW-23-7-20-W.4	Upper Till	32.7	70	3.23×10^{-5}	2.28×10^{-3}
NW-23-7-20-W.4	Upper Till	52.6	70	2.36×10^{-5}	1.65×10^{-3}
NW-23-7-20-W.4	Lenzie Silts	80.1	10	2.82×10^{-5}	2.82×10^{-4}
SW-5-30-7-20-W.4	Upper Till	96	120	4.18×10^{-3}	5.02×10^{-1}
SW-5-30-7-20-W.4	Upper Till	97	120	8.52×10^{-4}	9.6×10^{-2}
SW-5-30-7-20-W.4	Upper Till	156.5	39	2.75×10^{-3}	1.08×10^{-1}
SW-8-8-20-W.4	Upper Till	19.3	100	7.35×10^{-4}	7.35×10^{-2}
SW-18-8-20-W.4	Upper Till	31.6	130	6.1×10^{-5}	7.8×10^{-3}
SW-18-8-20-W.4	Upper Till	51.6	130	2.3×10^{-5}	3.0×10^{-3}
SW-18-8-20-W.4	Upper Till	82.3	130	4.15×10^{-4}	5.4×10^{-2}
NE-34-8-20-W.4	Upper Till	35.0	80	6.36×10^{-5}	5.1×10^{-3}
NE-34-8-20-W.4	Lenzie Silts	83.2	15	5.1×10^{-5}	7.6×10^{-4}
SW-14-9-19-W.4	Upper Till	79.3	104	2.6×10^{-3}	2.7×10^{-1}
SW-14-9-19-W.4	Basal Till	159.3	11	1.21×10^{-3}	1.33×10^{-2}
SE-1-21-W.4	Upper Till	48.4	60	1.97×10^{-5}	1.18×10^{-3}
NE-8-10-20-W.4	Upper Till	5.27	60	3.15×10^{-5}	1.89×10^{-3}

Lenzie Silts: Average $T = 0.83 \times 10^{-3}$

Upper Till: Average $T = 0.76 \times 10^{-1}$

GEOLOGY

Bedrock geology of the basin is shown in Figure 12. The Oldman-Foremost contact has been revised through interpretation of the many available drill-hole logs and extrapolation over the bedrock topography map (Figure 13).

The Bearpaw-Oldman contact used was that drawn by Geiger (1968). Both of these geological contact differ somewhat from those in existing publications. By taking into consideration the irregularities of the bedrock topography, it is hoped that this map will more nearly represent reality.

Surficial geology of the Lethbridge area was mapped by Stalker in 1962. A simplified version of the part within the basin is included as Figure 14.

Inasmuch as active groundwater movement extends downward through the Milk River Sandstone, the various geological horizons higher than its base have been mapped. This was done by interpretation of both oil company and water well electric logs.

The top of the Colorado Group is the lower boundary of groundwater movement. Its elevation is shown in Figure 15. The lowest aquifer used in this area is the Milk River sandstone which lies directly upon the Colorado Shale. Its configuration is shown in Figure 16.

The Pakowki Shale overlies the Milk River Sandstone and has a thickness of about 100 to 150 feet. The elevation of the top of the Pakowki Shale is shown in Figure 17.

Over the Pakowki Shale are the Foremost and Oldman Formations, known collectively as the Belly River Group. These two formations, consisting of

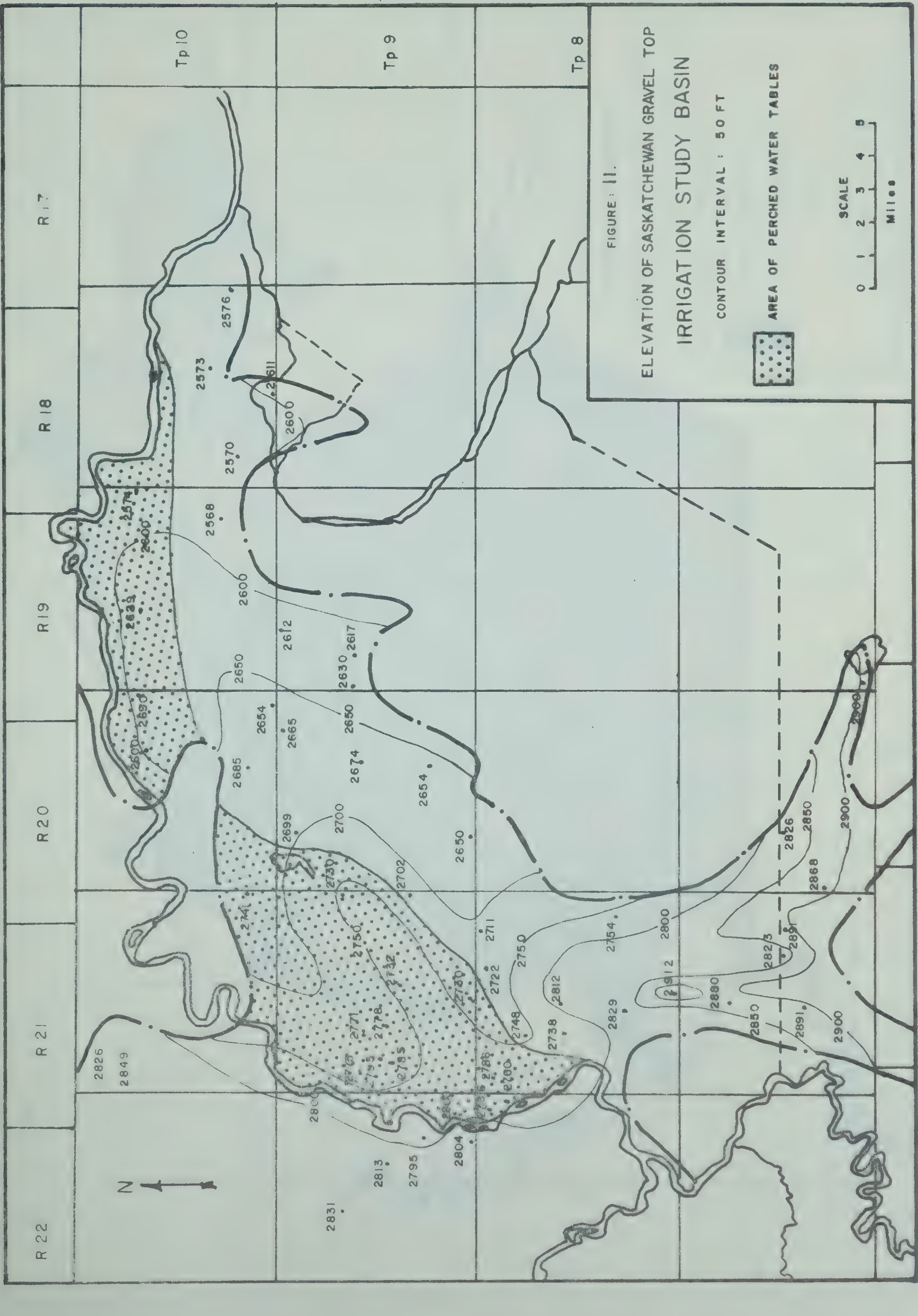


FIGURE: 11.

ELEVATION OF SASKATCHEWAN GRAVEL TOP

IRRIGATION STUDY BASIN

CONTOUR INTERVAL: 50 FT

AREA OF PERCHED WATER TABLES

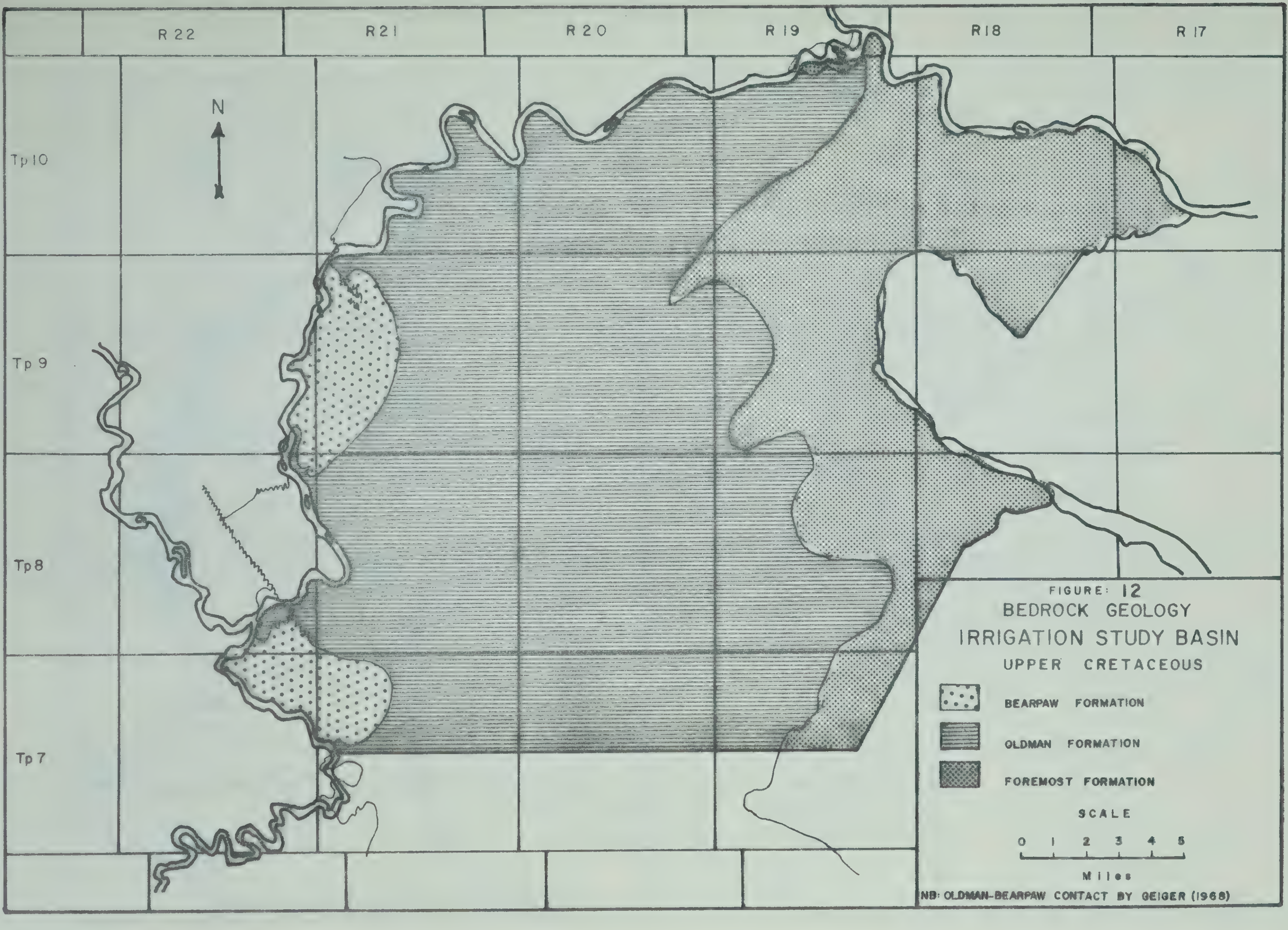


FIGURE: 12
BEDROCK GEOLOGY
IRRIGATION STUDY BASIN
UPPER CRETACEOUS

NB: OLDMAN-BEARPAW CONTACT BY GEIGER (1968)

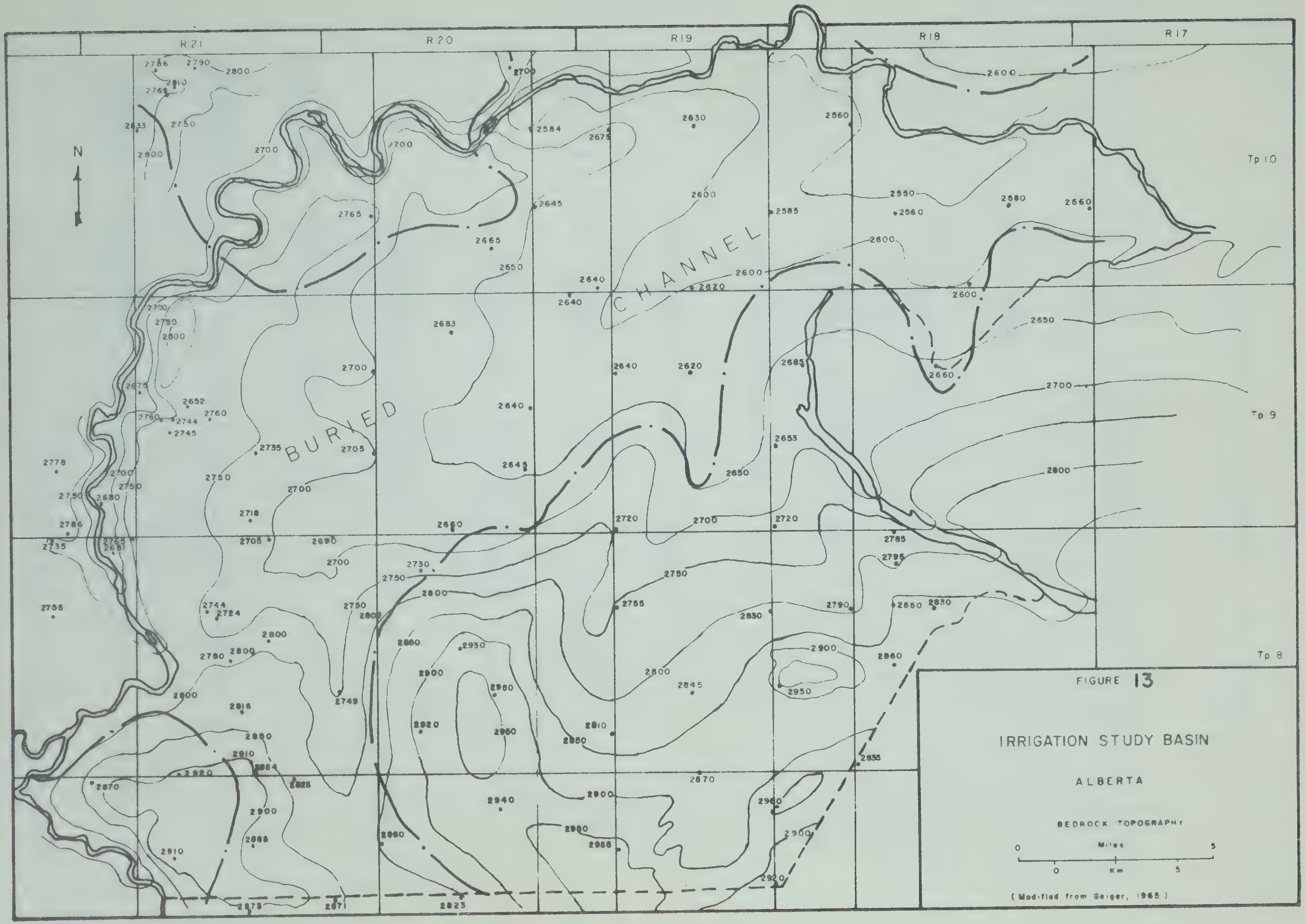


FIGURE 13

IRRIGATION STUDY BASIN

ALBERTA

BEDROCK TOPOGRAPHY

(Modified from Geiger, 1965)

Figure 14.

Surficial Deposits - Irrigation Study Basin

Legend

Recent Deposits

▥ Aeolian deposits: Sand, silt

▤ Modern alluvium: Gravel, sand

▦ Terrace alluvium: Gravel, sand

Late-Glacial to Early Glacial Deposits

░ Lake deposits: Silt, sand, minor clay

□ Glacial spillway alluvium: Gravel, sand, silt, clay

Laurentide Glacial Deposits

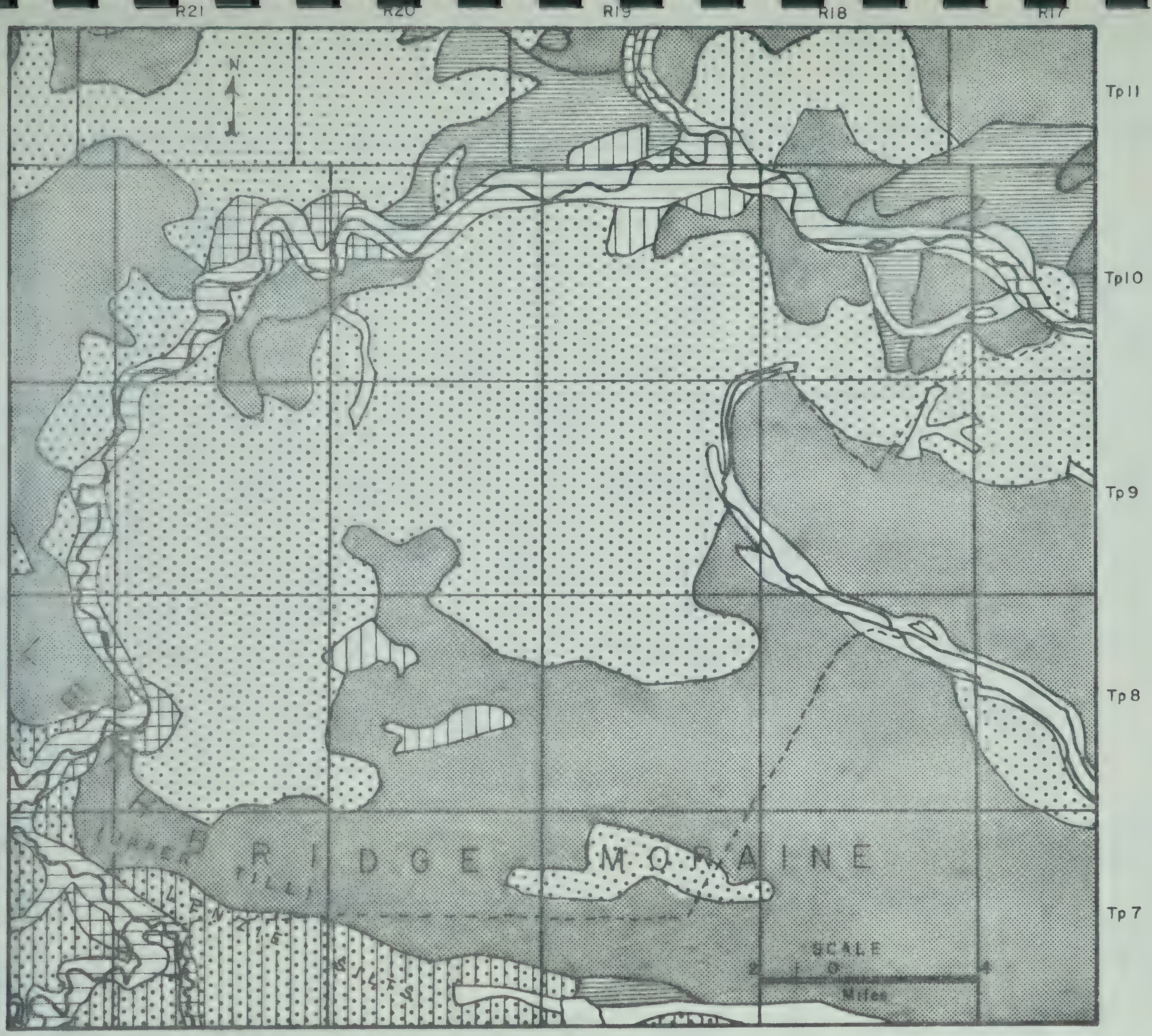
☰ Outwash and inwash: Gravel, sand, silt

▒ Hummocky and ground moraine (Lethbridge Moraine): Till

▩ Interglacial lake deposits (Lenzie Silts): Silt, clay, sand, gravel

Modified from: Stalker - Map 41-1962

Geol. Surv. Canada



SURFICIAL DEPOSITS - IRRIGATION STUDY BASIN

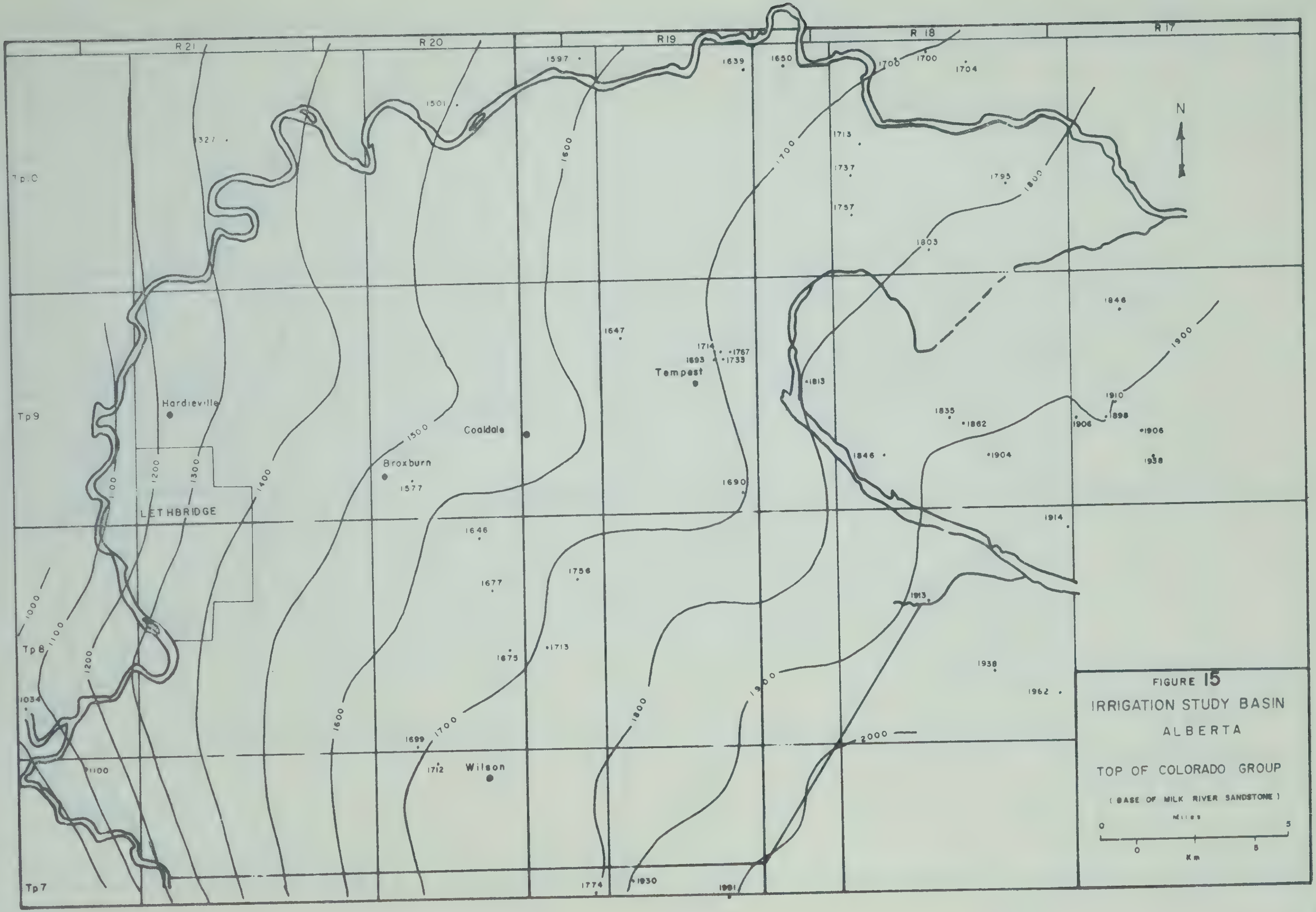


FIGURE 15
IRRIGATION STUDY BASIN
ALBERTA

TOP OF COLORADO GROUP

(BASE OF MILK RIVER SANDSTONE)

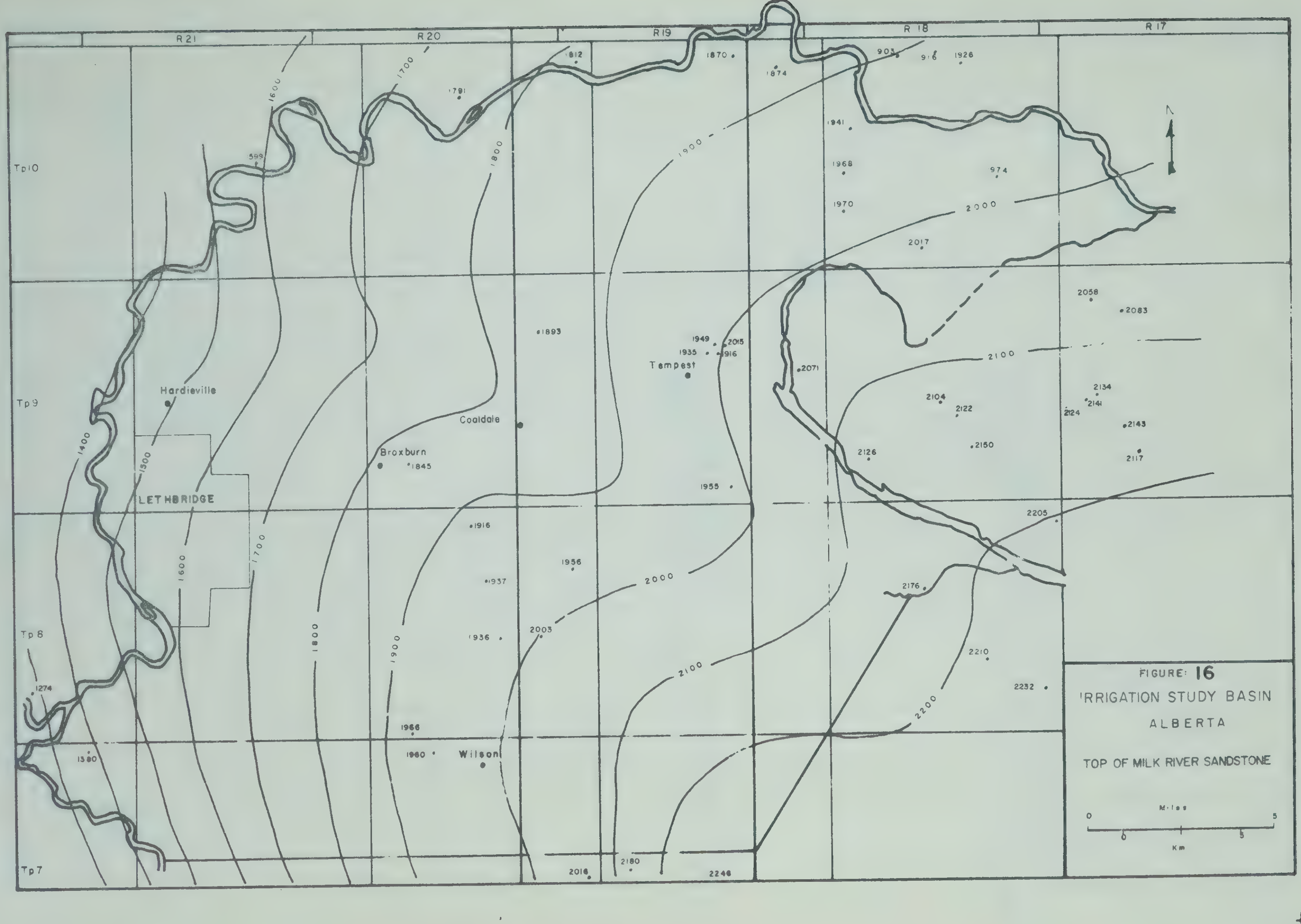


FIGURE: 16

'RRIGATION STUDY BASIN

ALBERTA

TOP OF MILK RIVER SANDSTONE

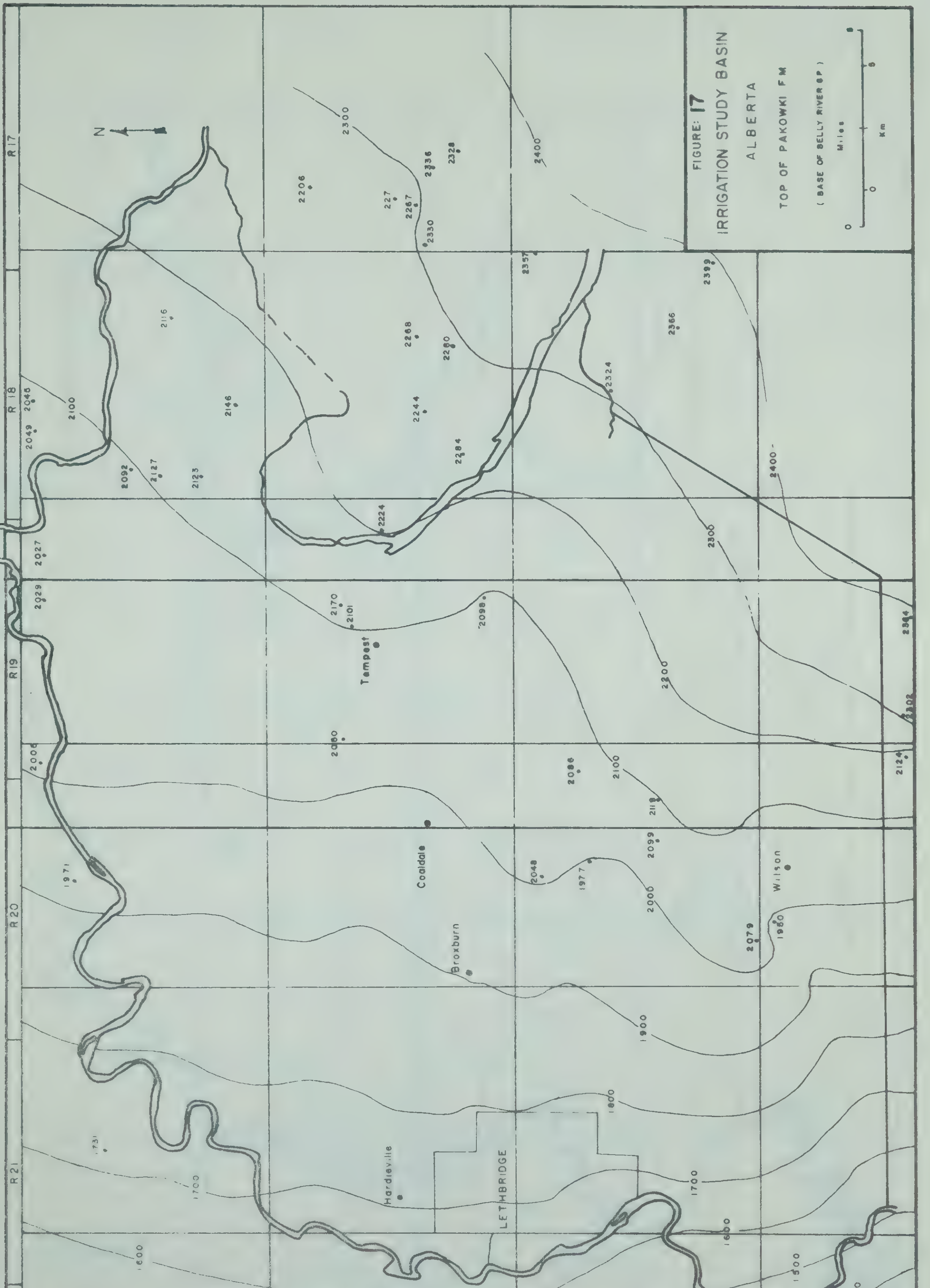


FIGURE: 17
IRRIGATION STUDY BASIN
ALBERTA
TOP OF PAKOWKI FM
(BASE OF BELLY RIVER GP)

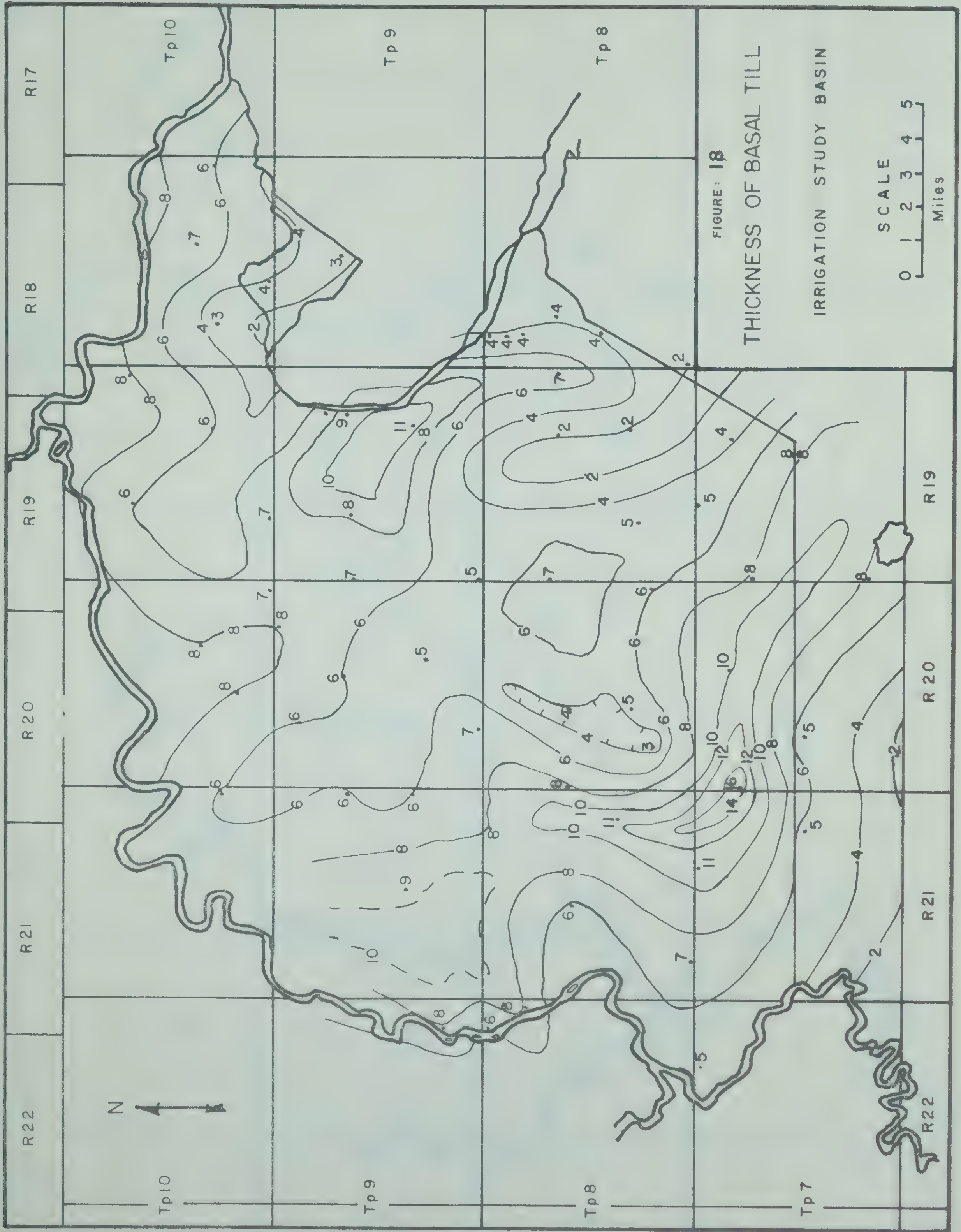


FIGURE: 18

THICKNESS OF BASAL TILL

IRRIGATION STUDY BASIN

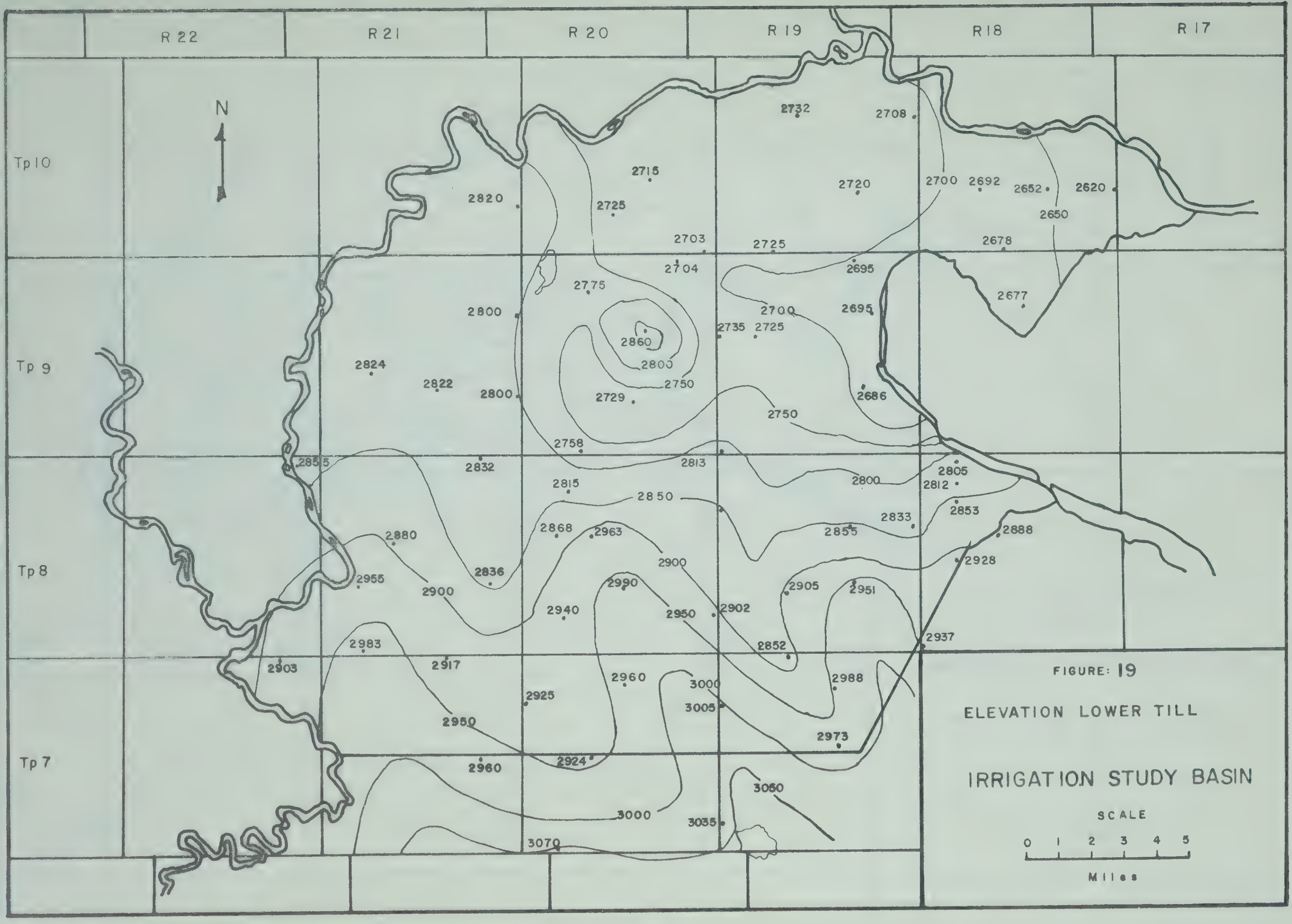


FIGURE: 19

ELEVATION LOWER TILL

IRRIGATION STUDY BASIN

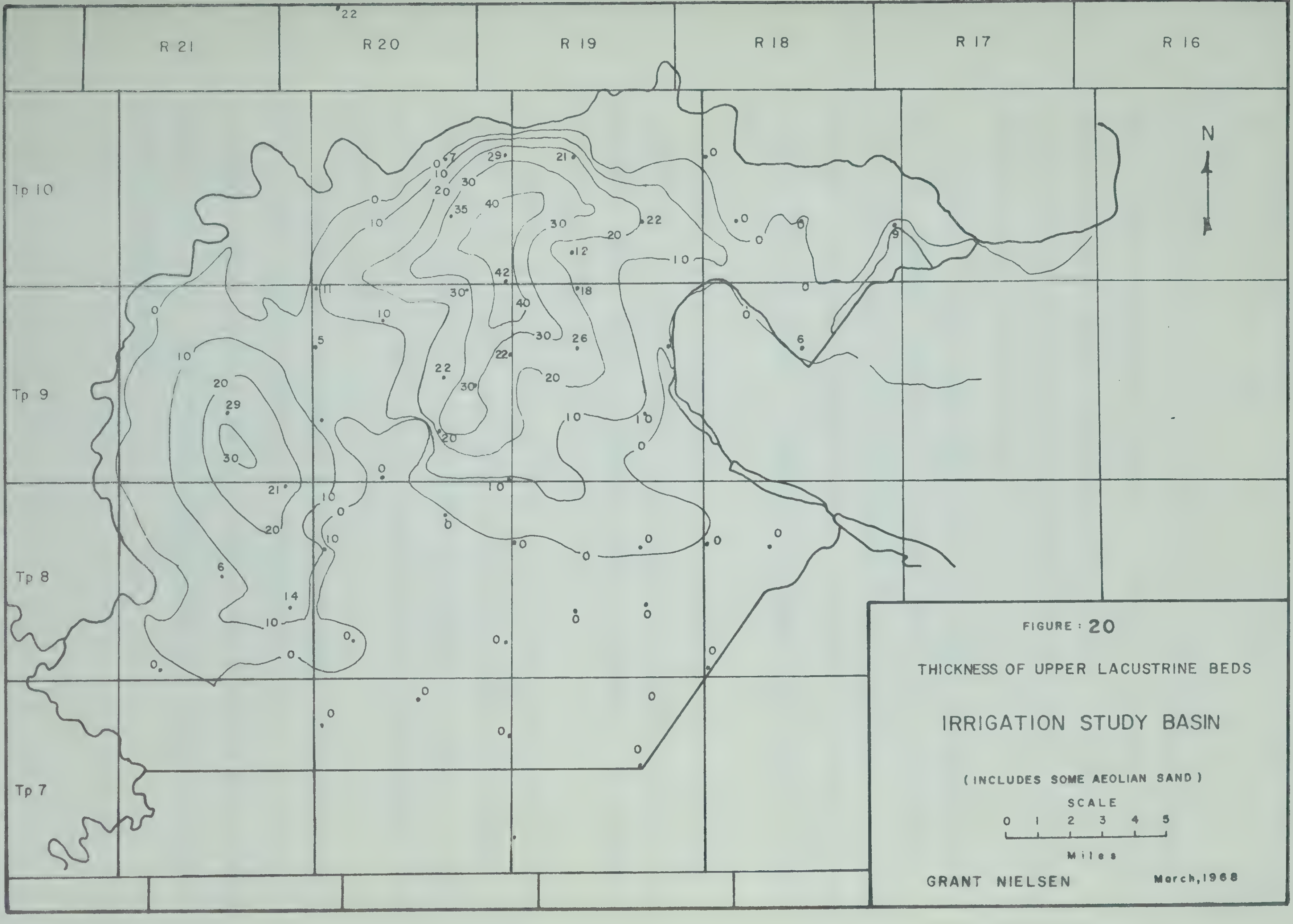


FIGURE : 20

THICKNESS OF UPPER LACUSTRINE BEDS

IRRIGATION STUDY BASIN

(INCLUDES SOME AEOLIAN SAND)

GRANT NIELSEN March, 1968

alternating layers of shale, sandstone and coal, form the subcrop surface under the surficial deposits of most of the basin. In preglacial time, a large river valley formed upon the bedrock of the area, leaving up to 40 feet of alluvial gravel behind. The elevation of this gravel, called Saskatchewan Gravel, is shown in Figure 11.

During Pleistocene glaciation, three till sheets, and two lacustrine beds were deposited. The lowest till, termed "Basal Till" lies directly over the Saskatchewan Gravel, or on bedrock, where the gravel is not present. This till is thin, not exceeding 16 feet in thickness. It is very hard, and occurs in vertical columns. Thickness of the Basal Till is shown in Figure 8.

Lower till is the term applied to the second till sheet. It is much thicker, and tends to be thickest over preglacial valleys and thinnest over preglacial ridges. Hence the thickness varies considerably. The elevation of its upper surface is shown in Figure 19.

Between the Lower Till and Upper Till, is a lacustrine deposit called "Lenzie Silts", from the type section at Lenzie just west of Lethbridge. This deposit outcrops south of the Lethbridge Moraine. The Upper Till overlies the Lenzie Silts and forms the Lethbridge Moraine. This feature forms the southern boundary of the study basin.

During glacial retreat downslope to the northeast, water was trapped in a temporary lake just north of the Lethbridge Moraine. Up to 40 feet of lacustrine sediments accumulated in this basin before the lake was completely drained (Figure 20). Some of these sediments have been subsequently reworked by wind and stream action.

CLIMATOLOGICAL SUMMARY

Climatological data other than that used in this study is collected for the Department of Transport. Figures 21, 22, 23, 24, and 25 give data on humidity, temperature, total wind mileage, evaporation and gross and net radiation respectively. While these data, except for evaporation, were not used in preparing this report, they may help explain other parameters used in the study.

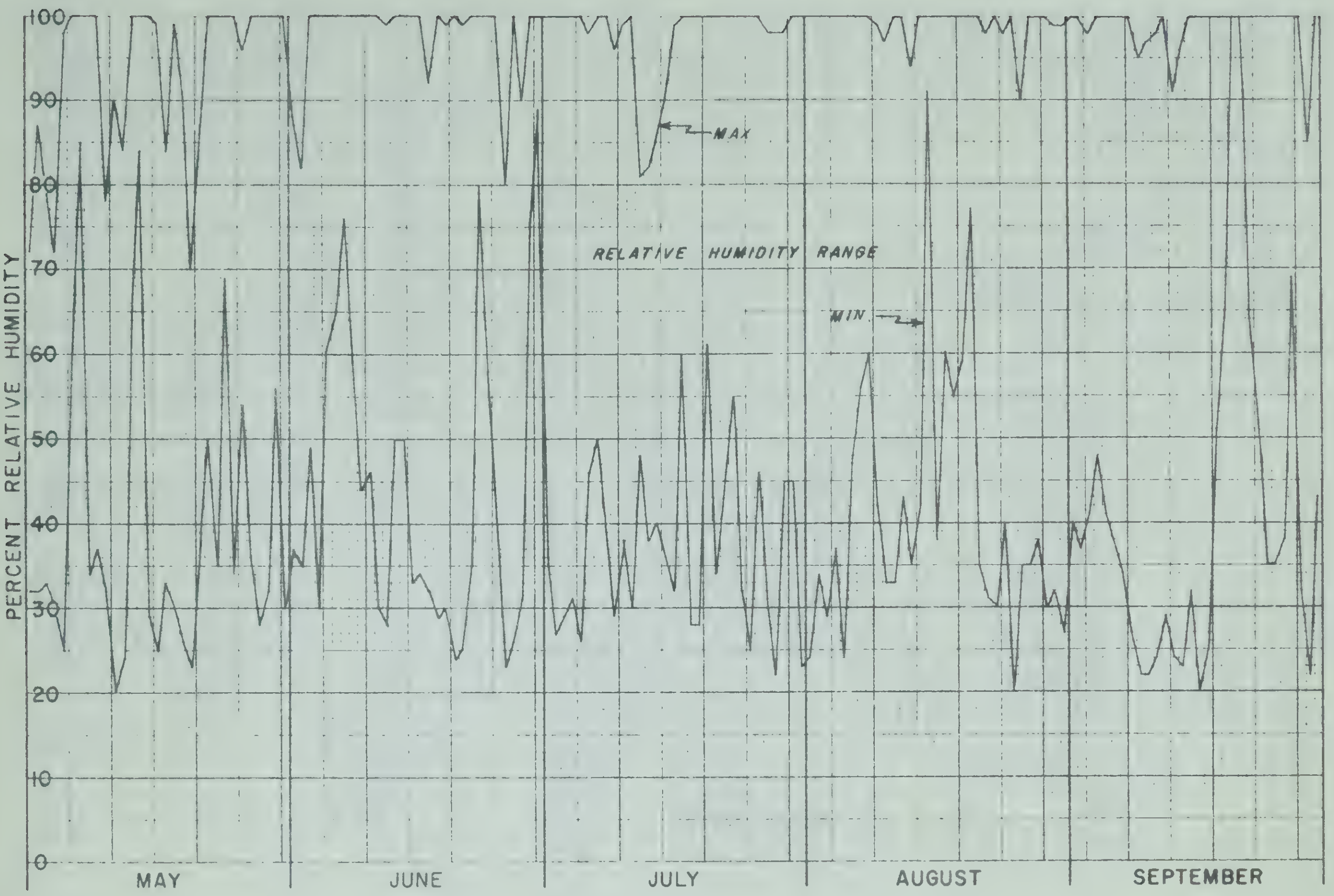


FIGURE 21 Daily Max.-Min. Levels of Relative Humidity - 1968 Growing Season

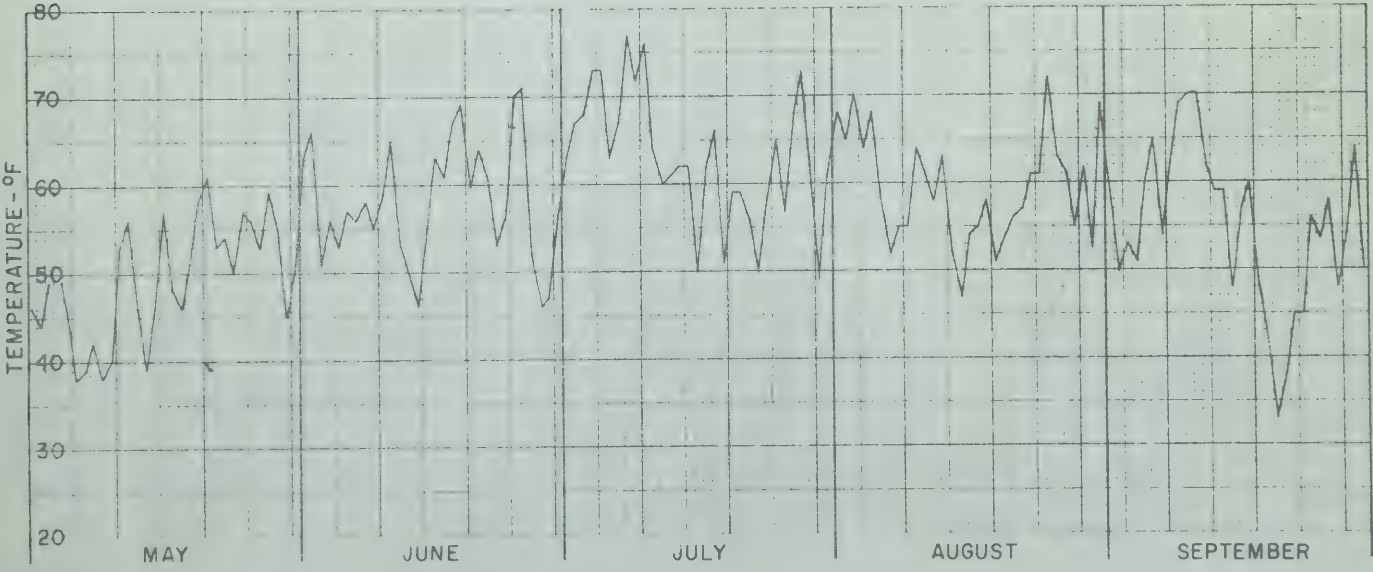


FIGURE 22 Average Mean Daily Temperature - 1968 Growing Season

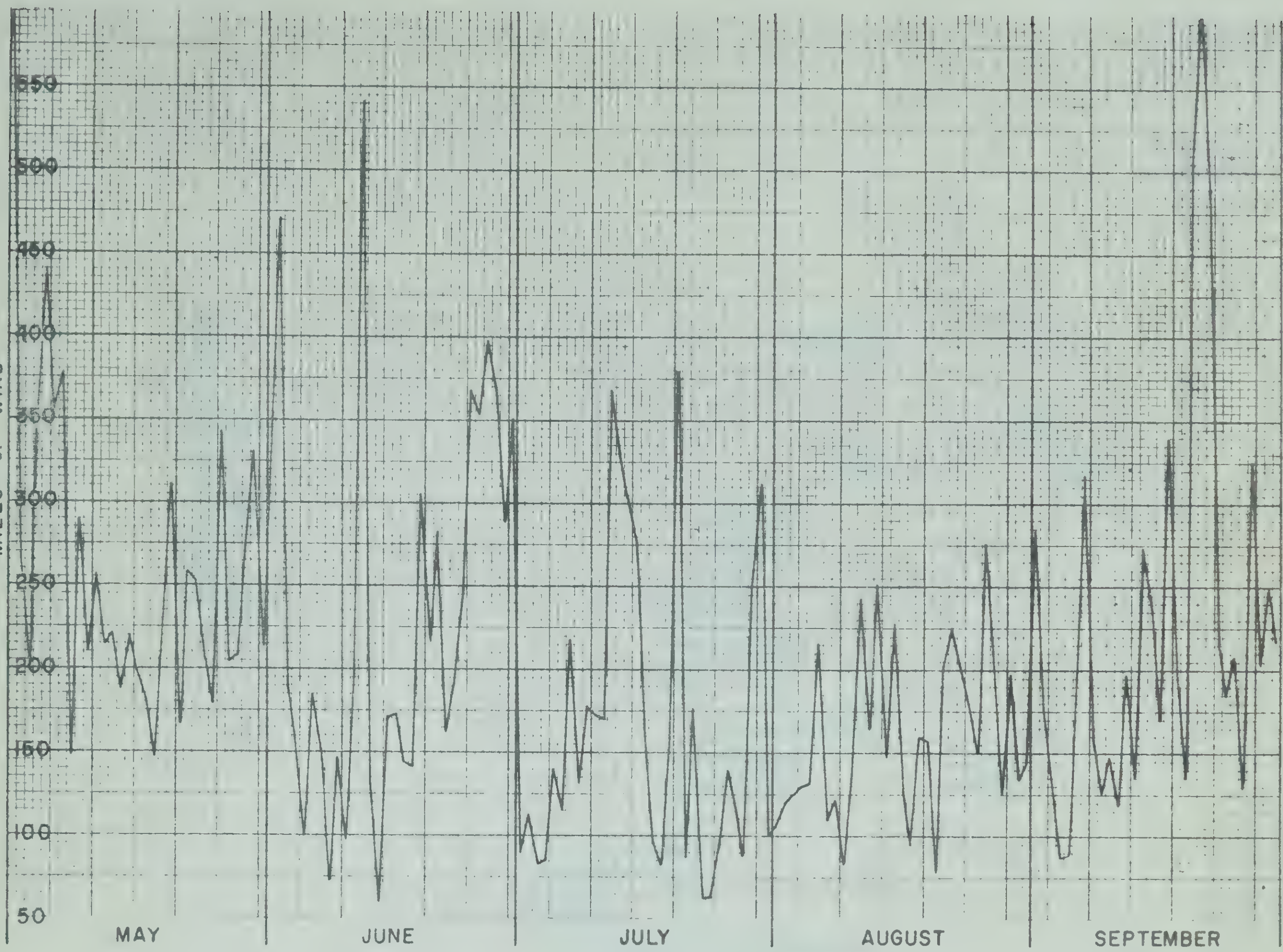


FIGURE 23 Total Daily Wind Mileage — 1968 Growing Season

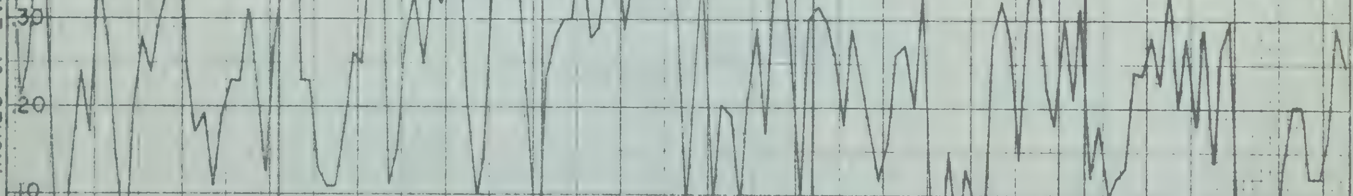


FIGURE 24 Average Daily Evaporation — 1968 Growing Season

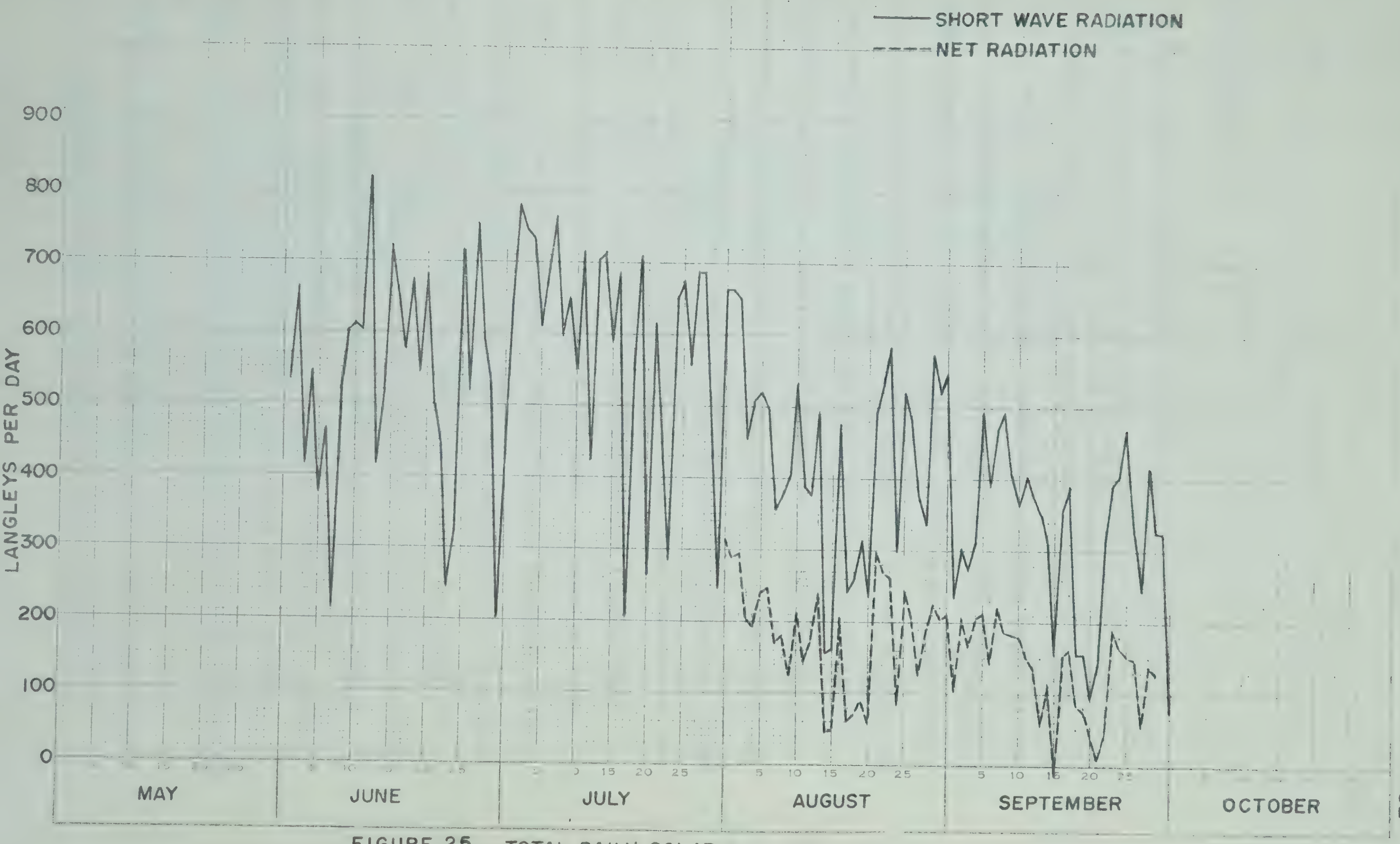


FIGURE 25 TOTAL DAILY SOLAR RADIATION – 1968

READYMADE SUB-BASIN

A total of eight stream gauging stations were installed in the sub-basin during the 1968 season. In the spring of 1969 the addition of two more stations will complete the hydrometric network within the mini-basin.

Three gauging stations have been established on inflow canals to the mini-basin. On the main inflow canal a Leupold-Stevens A-35 recorder, housed in a wooden culvert, has been installed directly above an existing wooden drop structure and thus a reliable, stable rating should exist for this station. The remaining two inflow canals are small and have an estimated capacity of about 5 cfs. These canals enter the mini-basin by crossing the western boundary road through steel culverts. The gauges on both of these canals consist of staff gauges installed directly above the culverts. These staff gauges are read daily by an observer. The discharge measurements made to date indicate that a relatively stable control exists at both sides.

A total of five return flow coulees have been instrumented in 1968. Three gauging stations sites consist of sandbag controls (sandbags filled with concrete and piled across the streambed thus acting as a broad-crested weir) with Leupold-Stevens F-type recorders used to record the stage. An inadequate number of dicharge measurements were made at each of these stations to develop rating curves and thus no mean daily discharges will be computed until the end of the 1969 season. Also the electric drive mechanisms for these recorders ran sporadically and thus much stage record was also missed. The recorders have been modified and should work well in the 1969 season.

Two more gauging stations will be installed on the major return flow channels in the mini-basin. These will consist of San Dimas flumes or

H-flumes, with Leupold-Stevens A-35 recorders used to record stage data, and will be installed previous to the 1969 irrigation season.

With the addition of these two gauging stations the hydrometric gauging of the mini-basin will be complete; although in addition to the recorded return flows estimates of the return flows through ungauged coulees will be made with the aid of observations of flow in these ungauged coulees taken on every visit to the mini-basin. Thus a fairly accurate return flow figure should be determinable.

In order to monitor groundwater movement, a north-south line of 5 piezometer nests was installed in September, 1968. The necessary materials and drill time for these installations were supplied by the Groundwater Division, Research Council of Alberta. Piezometer readings are not yet sufficient to permit interpretation of the groundwater regime of this area.

Instrumentation now in operation in the Readymade sub-basin is shown in Figure 26.

SUMMARY

It has been possible to establish this year a preliminary hydrologic budget for the basin, but only for the growing season, May 1 to September 30. Certain parameters, notably evapotranspiration, change in soil moisture, and change in groundwater storage, are not yet available on an annual basis. The bulk of evapotranspiration no doubt occurs during this five month period, but measurable quantities of water are used also during the balance of the year.

The hydrologic equation, modified from the 1967 report, is as follows:

$P + I = Et + Q + \Delta Sm + \Delta Sg + S + \Delta Ss$, in which

P = precipitation

I = irrigation

Et = evapotranspiration (consumptive use)

Q = surface runoff

ΔSm = change in soil moisture storage

ΔSg = change in groundwater storage

S = seepage and deep percolation

ΔSs = change in surface water storage

For the May 1 to September 30, 1968 period, the parameters are as follows, each having been evaluated independently:

$$P + I = Et + Q + \Delta Sm + \Delta Sg + S + \Delta Ss$$

$$241{,}320 + 64{,}570 = 232{,}110 + 4{,}320 + 3{,}000 + 69{,}160 - 700$$
(acre-feet)

$$11.29'' + 3.03'' = 10.89'' + .27'' + 0.22'' + 0.14'' + 3.24'' - 0.03''$$
(Inches)

$$79.1\% + 10.9\% = 73.9\% + 1.8\% + 1.4\% + 0.9\% + 22.0\% - 0.2\%$$

This equation fails to balance by 7,760 acre-feet or 0.41 inches of water lacking on the left-hand side of the equation. This is a discrepancy of less than 2 per cent. Error is most likely in the seepage data and evapotranspiration estimates for various crops.

The 1969 report will hopefully contain such a budget for an entire calendar year, not just a five-month period.

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APPENDIX A - New Instrumentation

Equipment	Quantity	Data Recorded
Net radiometer	1	Continuous instantaneous net radiation
Standard raingauge	1	Total daily rainfall
Nipher snowgauge	1	Total daily precipitation
Deep Piezometer Nests	23 nests, 68 piez.	Deep groundwater movement
Differential Piezometer Nests	32 nests	Shallow and deep groundwater movement
Watertable wells	47 removed	Depth of water table
Recording gauging stations, natural bed	3	Streamflow
Non-recording gauging stations, natural bed	5	Irrigation inflow, Irrigation outflow

APPENDIX B - Representatives of Contributing Agencies

D. Cramer
P.F.R.A.
Lethbridge

R.K. Deeprose
Water Resources Division
Agriculture Bldg.
Edmonton

R. Francis
Water Resources Division
Lethbridge

J.M. Kelly
Water Resources Division
Lethbridge

A.S. Mann
Meteorological Branch
Dept. of Transport
Federal Bldg.
Edmonton

L.J. McCracken
Water Resources Division
Lethbridge

G.L. Nielsen, Co-ordinator
Water Resources Division
Agriculture Bldg.
Edmonton

L.D.M. Sadler
Water Resources Division
Agriculture Bldg.
Edmonton

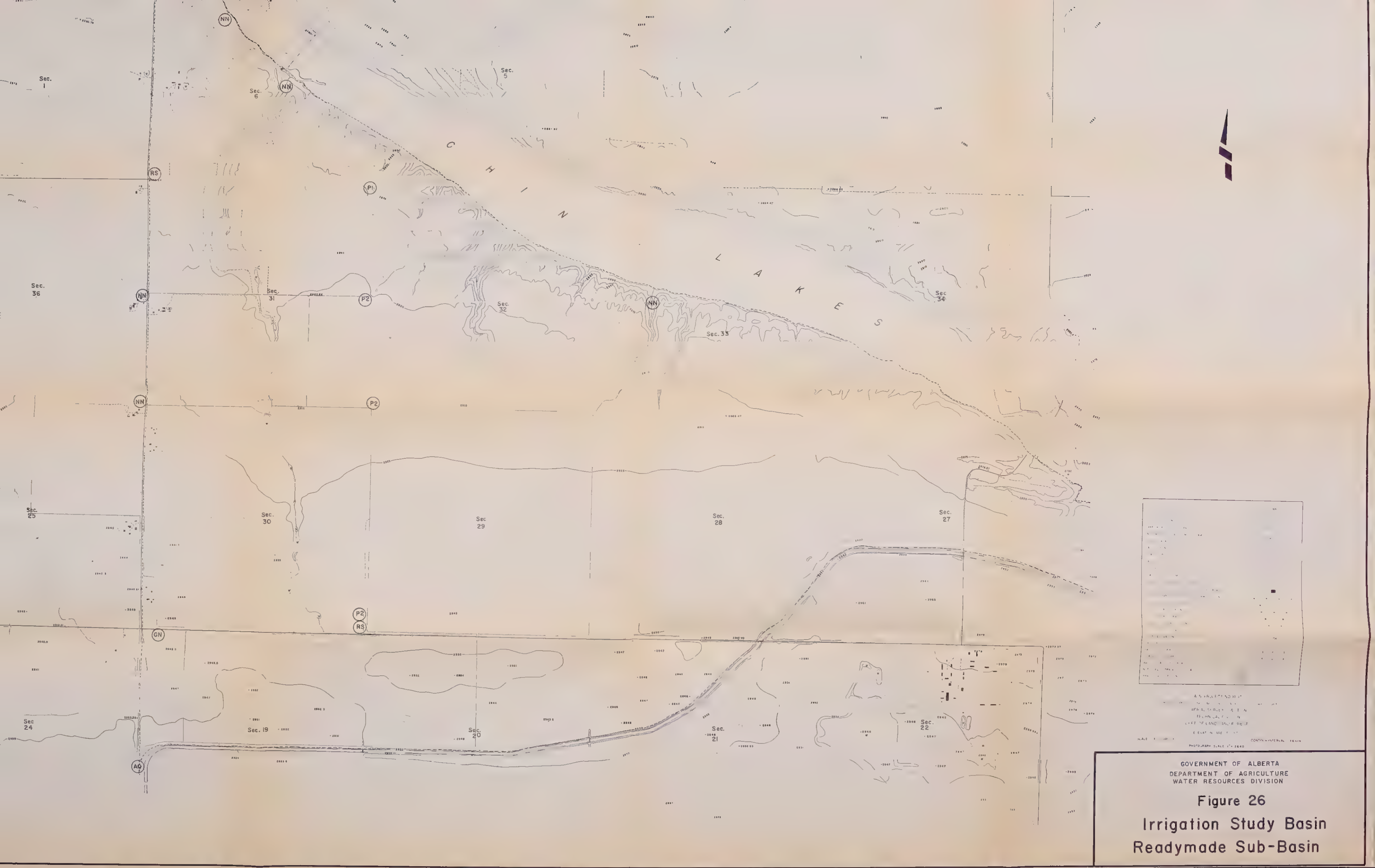
Dr. T. Sommerfeldt
Canada Research Station
Canada Dept. of Agriculture
Lethbridge

M. Spitzer
Water Survey of Canada
Calgary Power Bldg.
110 - 12 Ave. S.W. Calgary

G. Steed
Water Resources Division
Lethbridge

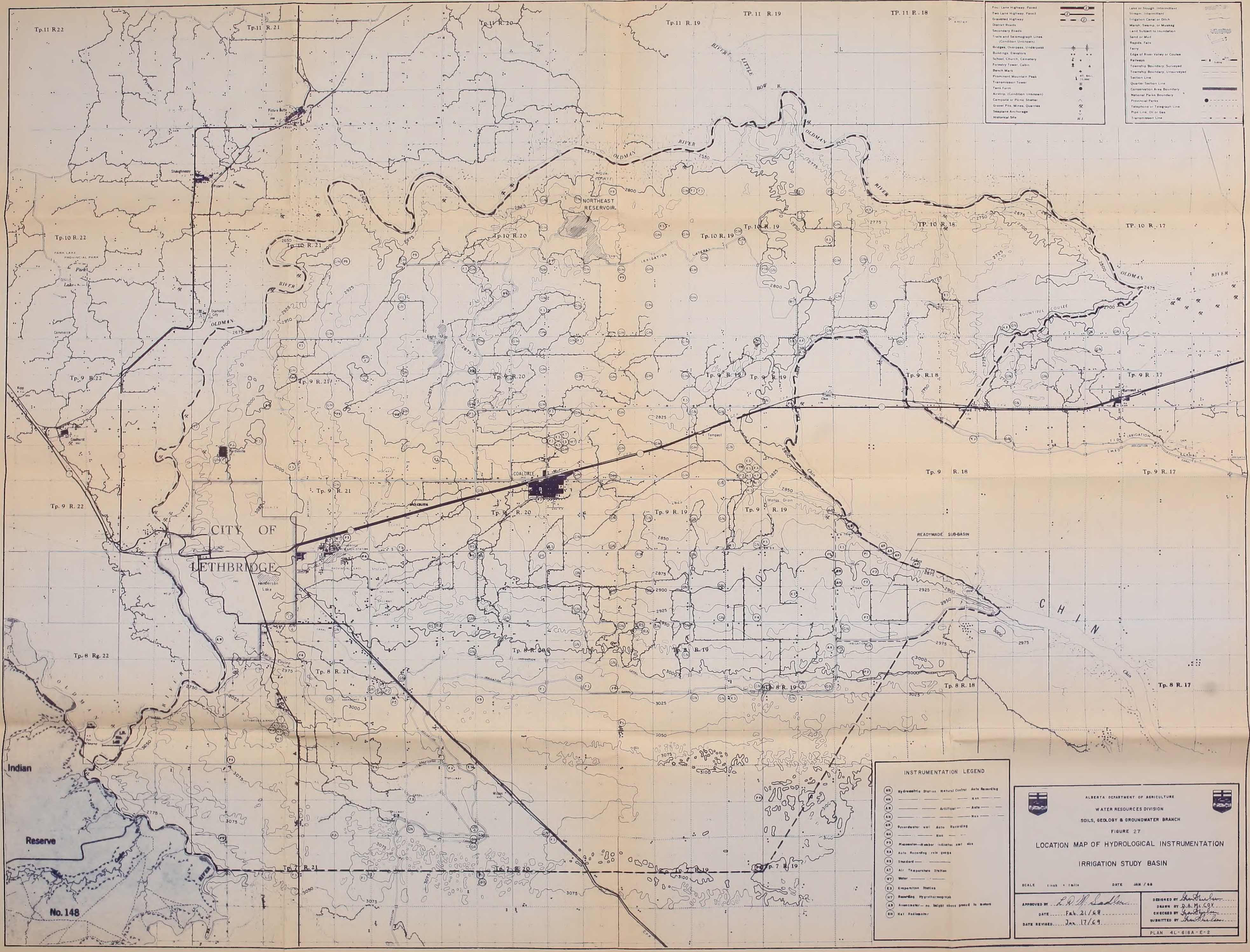
J. Thiessen
St. Mary River Irrigation District
Lethbridge

Dr. J. Toth
Research Council of Alberta
11315 - 87 Ave.
Edmonton



GOVERNMENT OF ALBERTA
DEPARTMENT OF AGRICULTURE
WATER RESOURCES DIVISION

Figure 26
Irrigation Study Basin
Readymade Sub-Basin



ALBERTA DEPARTMENT OF AGRICULTURE

WATER RESOURCES DIVISION

SOILS, GEOLOGY & GROUNDWATER BRANCH

FIGURE 27

LOCATION MAP OF HYDROLOGICAL INSTRUMENTATION

IRRIGATION STUDY BASIN

SCALE 1 inch = 1 mile DATE JAN / 68

APPROVED BY L. A. W. Sadler
DATE Feb. 21/68
DATE REVISED Jan. 17/69

DESIGNED BY
DRAWN BY D. A. McCOY
CHECKED BY
SUBMITTED BY

PLAN 4L-618A-E-2